Canadian Centre
for Occupational
Health and Safety

Centre canadien
d'hygiène et de
sécurité au travail

CURRENT ISSUES IN RADIATION SAFETY

A Seminar

P90-20E

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Hamilton, Ontario
May 29, 1990

Canadian Centre for Occupational Health and Safety

CCOHS/CCHST

93-00647/

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CCOHS NUMBER P90-20E

ISBN 0-660-13752-6

DSS CATALOGUE NUMBER CC273-2/90-20E

This proceedings of the Current Issues in Radiation Safety Seminar, May 29, 1990, in Hamilton, includes the presentations of speakers, discussions and questions of participants. It has been edited for publication in consultation with speakers.

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This publication is available in both official languages.
Cette publication est disponible dans les deux langues officielles.

Published 1990

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Canadian Centre
for Occupational Health and Safety

CURRENT ISSUES IN RADIATION SAFETY

A Seminar

Tuesday, May 29, 1990
Hamilton Convention Centre, Hamilton, Ontario

Tuesday, May 29, 1990

8:00 am	REGISTRATION and COFFEE
9:00 am	**Opening Remarks** Lillian Vine, Manager, Workshops and Conferences Canadian Centre for Occupational Health and Safety
9:15 am	**Introduction to Non-Ionizing Radiation** David Charron, Canadian Centre for Occupational Health and Safety
9:45 am	**VDTs - An Update** Bob DiMatteo, Ontario Public Service Employees Union
10:15 am	**Power Lines - Cancers and Other Concerns** Jan Deadman, School of Occupational Health McGill University
10:45 am	COFFEE BREAK
11:15 am	**Introduction to Ionizing Radiation** Bhawani Pathak, Canadian Centre for Occupational Health and Safety
11:45 am	**Radon - A Silent Killer?** Denis Brown, Saskatchewan Department of Human Resources, Labour and Employment
12:15 pm	LUNCH BREAK

1:30 pm	**Nuclear Industry - Hazards and Benefits** Gerry Armitage, Ontario Hydro
2:00 pm	**Radiation Safety in Uranium Mines Project - Communications** J L Chakravatti, Denison Mines
3:00 pm	COFFEE BREAK
3:30 pm	**Controversy and Credibility** Fergal Nolan, Canadian Institute for Radiation Safety
4:00 pm	**Close of Seminar**

CM POINTS

The American Board of Industrial Hygiene will award 0.5 Credit Maintenance points and the Canadian Board of Occupational Medicine will award 6 hours of CME Study Credits for participation at this workshop.

SUMMARY

CCOHS held a seminar on Current Issues in Radiation Safety on May 29, 1990, to review issues in both non-ionizing and ionizing radiation issues.

CCOHS scientists David Charron and Bhawani Pathak presented introductions to non-ionizing radiation and ionizing radiation respectively.

Bob DiMatteo of the Ontario Public Service Employees Union discussed a number of studies on VDTs--while they may be inconclusive and even sometimes contradictory, he said they do make a case for concern and caution.

Jan Deadman of the School of Occupational Health at McGill University spoke on power lines, cancers and other concerns. He reviewed current knowledge on issues; there are many unknowns and research is continuing.

Denis Brown of the Saskatchewan Department of Human Resources, Labour and Employment, described the risks of radon in buildings and ways to reduce it.

Gerry Armitage of Ontario Hydro concluded that the benefits of nuclear energy far outweighed the risks.

J L Chakravatti of Denison Mines briefly described the communications project undertaken at Denison Mines with CCOHS; the videotex package was developed with input from the Atomic Energy Control Board and the union at Denison Mines. Training is being enthusiastically carried out by union trainers. Firmly believing that a picture is worth a thousand words, Mr Chakravatti invited participants to see for themselves; at every break highly interested groups were gathered around the computer terminal.

Fergal Nolan of the Canadian Institute for Radiation Safety described his organization and attributed its credibility, in a field where controversy reigns, to its neutrality--it takes no positions.

INTRODUCTION

Lillian Vine

Welcome to the CCOHS seminar on Current Issues in Radiation Safety. We have excellent speakers, all of whom have come here because they wanted to--at their own expense. We are extremely grateful to them for this contribution to CCOHS. Thank you very much.

We briefly reviewed their presentations very early this morning; you have an interesting day ahead of you. At the back of this room is a computer terminal that will be used by Mr Chakravatti in his demonstration of the project he is describing. This will give you a first-hand idea of the program so you can ask specific questions about it.

The Canadian Centre for Occupational Health and Safety is a service organization and we want to serve you as well as possible. To do that we need your feedback. I have very much welcomed the feedback that I have received from you either at the workshops or through a note or a phone call. Sometimes it is a criticism, and we take it very seriously and try to respond to it; sometimes it is a compliment and we like these very much.

We decided just a short time ago to start using an evaluation form. I would appreciate it if you would fill it out before you leave and if you would also comment on the evaluation form itself.

PRESENTATIONS

Introduction to Non-Ionizing Radiation
David Charron, Canadian Centre for Occupational Health and Safety

VDTs - An Update
Bob DiMatteo, Ontario Public Service Employees' Union

Power Lines - Cancers and Other Concerns
Jan Deadman, McGill University

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INTRODUCTION TO NON-IONIZING RADIATION

Lillian Vine

As always, I will introduce the speakers much more briefly than they deserve. Our first speaker is David Charron. David is a Project Scientist with the Physical Hazards Group at the Canadian Centre for Occupational Health and Safety. He specializes in the health effects, hazard control measures, measurement and other aspects of non-ionizing radiation. David will give an introduction to non-ionizing radiation.

David Charron

In the next few minutes I would like to answer some questions about non-ionizing radiation: What is it? Where is it used? What are its sources in the workplace? What are some of the known or suspected health hazards of exposure to non-ionizing radiation?

What is Non-Ionizing Radiation?

Health and Welfare Canada defines non-ionizing radiation as:

> A collective term given to a group of electromagnetic radiations which have longer wavelengths and less energy than ionizing radiation. It also includes static electric and magnetic fields and includes acoustic energy.

I would like to exclude the acoustic energy portion of non-ionizing radiation and concentrate solely on the electromagnetic radiation.

What is electromagnetic radiation? Quite simply, it is energy that travels through space. It could be natural, such as sunlight, or it could be man-made, for example the microwaves in your microwave oven.

There are two types of electromagnetic radiation, ionizing and non-ionizing. An example of electromagnetic ionizing radiation is x-rays. Ionizing radiation has enough energy to produce ions by knocking electrons loose from molecules, as illustrated in Figure 1.

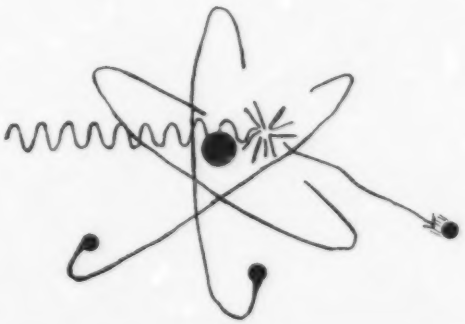


Figure 1

On the other hand, non-ionizing radiation, by definition, does not have enough energy to dislodge electrons from molecules but it can do other things.

Figure 2

Figure 2 shows electromagnetic non-ionizing radiation causing a molecule to vibrate. That is just one way that the radiation can act on molecules. That still does not leave us with a very good understanding of what non-ionizing radiation is, so let's look at another definition.

The International Radiation Protection Association (IRPA) defines non-ionizing radiation as electromagnetic energy with wavelengths greater than 100 nanometers (nm) and having energy less than 12 electron volts (eV). This includes:

Ultraviolet radiation	100 nm $\leq \lambda \leq$ 400 nm
Visible light	400 nm $\leq \lambda \leq$ 760 nm
Infrared radiation	760 nm $\leq \lambda \leq$ 1 nm
Radiofrequency radiation	300 Hz $\leq f \leq$ 300 GHz
Extremely low frequency fields	$f \leq$ 300 Hz Mainly 50/60 Hz

The various types of electromagnetic radiation are often illustrated in a chart called the electromagnetic spectrum. It shows the various types of radiation according to their frequency.

Figure 3 - The Electromagnetic Spectrum

The difference between ionizing and non-ionizing radiation is shown in Figure 3; x-rays and gamma rays are part of the ionizing radiation spectrum. Ultraviolet, visible light, infrared, radiofrequency radiation (which includes radiofrequencies and microwaves), and extremely low frequency fields make up the non-ionizing radiation portion.

The following table gives the typical units of measurement for each type of radiation which falls under the non-ionizing radiation definition. Optical radiation (ultraviolet, visible and infrared) is usually measured by its power density in milliwatts per square centimetre (mW/cm^2). Also, radiofrequency fields can be measured by its power density (mW/cm^2). Or, the individual electric and magnetic fields that make up the electromagnetic wave can be measured separately, so the electric field would be measured in volts per metre (V/m) and the magnetic field in amperes per metre (A/m).

Extremely low frequency fields are always expressed in terms of the individual electric and magnetic field components, as returned above.

UNITS OF MEASUREMENT - NON-IONIZING RADIATION

TYPE OF NIR	UNITS
Ultraviolet	mW/cm^2; J/m^2
Visible and Infrared	mW/cm^2
Radiofrequency	mW/cm^2; V/m; A/m
Extremely low frequency	V/m (electric)
	A/m, mG, mT or uT (magnetic)
Static electric fields	V/m; kV/m
Static magnetic fields	A/m, mG, mT or uT

Applications and Sources of Non-Ionizing Radiation

Let us look at some of the sources or applications of non-ionizing radiation that we find in the workplace and in everyday life, as illustrated in the following table.

Type of NIR	Devices
Static Magnetic Fields	* magnetic resonance imaging devices * electrolysis * aluminum smelting
Power Frequency Fields	* electricity generation and delivery systems * all electric and electronic devices
Radiofrequency and Microwave Radiation	* AM, FM, TV transmission * dielectric and induction heaters * two-way radios, cellular phones * medical diathermy * radar * microwave ovens
Infrared Radiation	* infrared heaters, infant incubators
Light	* all electrical lighting sources
Ultraviolet Radiation	* sunlamps * industrial sterilizers * welding arcs
Laser Emissions	* scanners * demonstration devices * construction alignment systems * surgical tools * welding and cutting

Health Hazards

The following summarizes some of the known or suspected health hazards of exposure to non-ionizing radiation.

Type of NIR	Health Hazards
Ultraviolet	Eye: Photokeratitis Conjunctivitis Cataract Skin: Skin burns Premature aging Skin cancer

Type of NIR		Health Hazards
Visible and Near-Infrared		Eye: Retinal injury Cataract Skin: Skin burn
Radiofrequency	Thermal:	Heat and burn tissue Cataracts, reproduction
	Non-Thermal:	Central nervous system Cardiovascular system Reproduction
	Safety:	RF shocks and burns Radiofrequency interference
Static and ELF Fields		Magnetophosphenes Central nervous system Cancer

Summary

Non-ionizing radiation is electromagnetic in nature; it contains very low energy and consists of ultraviolet, visible, infrared, radiofrequencies including microwaves, extremely low frequency fields and static fields. This introduction is aimed to illustrate some of the sources and applications of non-ionizing radiation in the workplace and to review some of the health effects of exposure.

If you require more information, please contact us at CCOHS.

QUESTIONS AND DISCUSSION

Robert Leslie - United Steelworkers of America

What is the difference between Ultraviolet A and Ultraviolet B radiation?

David Charron

Simply the wavelength. The ultraviolet radiation band itself is broken into three divisions--A, B and C. They are different wavelengths. Ultraviolet A is closest to visible light, and B and C are further away. The wavelength is shorter and the health effects of exposure are more severe with B and C.

VDTs - AN UPDATE

Lillian Vine

Our next speaker I have heard referred to as the authority on VDTs; I am delighted that Bob DiMatteo is with us today. Bob is Occupational Health and Safety Coordinator for the Ontario Public Service Employees Union and currently is also acting director of education and research for OPSEU.

He has been with OPSEU for the past 15 years, during which time he has conducted research and published many articles on occupational health and in particular on the health impact of technological change. He has published a comprehensive book entitled "Terminal Shock" which covers a wide spectrum of issues on the health impact of video display terminals. One of his current research interests is the health impact of electromagnetic fields. Before he started work at OPSEU, Bob was a university teacher and researcher.

Bob DiMatteo

I appreciate having been invited here to speak on this topic on which I have probably already spoken too much. I will discuss possible hazards of VDT radiation, particularly on reproductive outcomes, look at where this issue came from, what kinds of developments have taken place, what evidence there is and what it says and does not say, and where it is going from here.

Only a few years ago, after clusters of adverse reproductive outcomes were reported, there was a fantastic amount of resistance, particularly from regulatory authorities, to take this problem seriously at all. It was basically dismissed. In fact, as the clusters were being recognized, most regulatory bodies chalked them up to events more likely to occur by chance alone.

And, without exception, almost every official said it was absolutely impossible that radiation from VDTs could cause these kinds of problems. You can see that this issue has evolved from officials saying there is no radiation coming from VDTs whatsoever to saying there is radiation coming from VDTs, but not of the type that can harm you. And moving into a new phase of saying there is radiation, it is possibly harmful but the levels are not that high and could not harm you. There has been an evolution, but the debate is characterized by a fairly stubborn resistance to do anything about it. Unfortunately, as a result, research and enlightenment on the issue have been sluggish.

At the time that scientists and regulatory officials were saying these things, very few were fazed by the absence of any experimental data to support their positions. Few scientists seemed to notice the absence of data or evidence and very few were willing to even challenge this position. The public was assured that there was no radiation emitted from VDTs that could harm anyone well before very low frequency energy and extremely low frequency energy emanating from VDTs had been empirically characterized or even properly measured. We did not know what was coming out of those sets--I find it hard to believe, since the cathode ray tube which is the source of this has been around for at least 50 years, that the electrical engineers working on these devices for the manufacturers did not know.

The public was assured that the emissions from VDTs were far below accepted national and international standards. Even though these officials knew that there were no standards established for VLF or ELFs emitted by VDTs. The public was also assured that there was no evidence to suggest any greater danger from VDT radiation than from exposure to electricity from home appliances such as toasters or mixers. In many instances, these officials conveniently forgot to mention that electromagnetic fields coming from VDTs are non-sinusoidal or, though there is more debate on that, pulsed fields, while the fields from home appliances and from overhead lighting are not. And the public was not told that pulsed fields generally tend to be more biologically active. One spends a significantly greater amount of time working on a VDT than working with hand mixers or electric drills or power saws. Chronicity of exposure too is forgotten.

I would say that we have entered a new phase. When we started off, there was very little information about this whole area. There was very little direct evidence, animal or human, about the VLFs being emitted from VDTs. What we did know was coming from other related frequency ranges, particularly with respect to pulsed electromagnetic fields which people had started to suspect might be a source of a problem.

Employer	Time Frame	Rate of Adverse Outcomes	+ Chance Probability based on 21%	Type VDT	VLF Emission Level
USA					
Defence Logistics Agency Ga Marietta, Ga	Oct 79 Oct 80	67%	1.5 in 10,000	Motorola Phase IV	>1000V/m*
Sears Dallas, Texas	May 79 June 80	67%	7.3 in 10,000	Motorola Phase IV	>1000V/m*
Pacific NW Bell Renton, Wash	July 80 Aug 82	60%	5.8 in 100	Motorola Display XM353-27	>1000V/m*
United Airlines San Francisco	1979-84	50%	6.1 in 1,000,000	Honeywell Incoterm #10306	N/A
Southern Bell Atlanta, Ga	1983	40%	5.1 in 100	Western Electric Computer Console Model 4500	N/A
GTE Alma, Michigan	Dec 81 Mar 83	53%	4.9 in 100,000	Tandy TRS-4	800-1700V/m*
Canada					
Toronto Star Toronto, Ont	May 79 May 80	57%	N/A	N/A	N/A
Air Canada Montreal, Que	Feb 79 Feb 80	54%	7.5 in 1,000	Raytheon/ Westinghouse	N/A
Attorney General Toronto, Ont	1980-81	53%	1.58 in 1,000	Sycor 1500-5	>300V/m**
Solicitor General Ottawa, Ont	1979-82	67%	4.7 in 10,000	Micom 2000	>300V/m***
Surrey Memorial Hosp and 7 others Surrey, BC	1978-82	79%	6.2 in 1,000,000	Perkin-Elmer 1200 (Motorola)	>1250V/m****
Queen's Univ. Library Kingston, Ont	1980-84	100%	8.6 in 100,000	GEAC	>1000V/m*****
Europe					
Dept of Public Employment Runcorn, England	1974-82	36%		N/A	N/A
Public Library Aarhus, Denmark	1978-84	80%	1.1 in 10,000	N/A	N/A

* Radiation Environmental Management Systems, Radiation Surveys of over 4,000 VDTs
** Ontario Ministry of Labour, Measurement of Sycor Models used by subjects at Old City Hall
*** Health and Welfare Canada, "Investigation of Radiation Emissions from VDTs" 1983-EHD-91
**** Sharma, Hari, "The Investigation of a Cluster of Adverse Pregnancy Outcomes and Other Health Related Problems Among Employees Working with VDTs in the Accounting Office at Surrey Memorial Hospital, Vancouver, BC" June 1984
***** Radiation Environmental Management Systems, Radiation Measurements on the same model of VDTs used at the Ontario Legislative Library, Queens Park, 1982
\+ Chance probability refers to the likelihood that the cluster occurred as a result of chance alone where the expected rate in the general population is as high as 21%
Calculations provided by Dr Hari Sharma, University of Waterloo

Figure 4

Figure 4 illustrates the number of adverse reproductive-outcome clusters that have been recorded and documented. It indicates the rate of adverse outcomes, the probabilities of these events occurring by chance, the types of VDT use, and the probable emission level in the electric or magnetic field, depending on what was available to us.

The initial position taken by people in the regulatory agencies was that these were rare events, that they could be chance events. The Centres for Disease Control and several others, making certain assumptions about the employment structure, worked out some probabilities about how rare or frequent these events might be.

The first predictions of probability estimates were made in 1981 by Binkins and Associates. They would expect an event like the one that occurred at the Toronto Star in which 4 out of 7 pregnancies resulted in children born with birth defects. You would expect 5 to 6 clusters to occur per year.

More recently, Lucien Abenhaim of the National Institute of Health and Medical Research in France pointed out that these estimates were overestimates of the chance occurrence of such clusters because of erroneous assumptions about the employment structure. Abenheim delivered a paper at the Work With Display Units Conference in Montreal in 1989 to show that the assumptions were erroneous. When corrected based on his own calculation, the event at the Toronto Star would be expected to occur once every 25 years.

It was not acceptable to just dismiss this problem as a chance event. Abenhaim pointed out that the women who were concerned and involved in these clusters had every legitimate reason to be concerned and to be anxious about what was happening to them. According to Abenheim, the regulatory authorities should have moved much more quickly to conduct the research than they did. Very little research has been conducted in this particular area; most of it comes from the Scandinavian countries. Just recently the Canadians have done some research on the biological effects of VLF fields. There have been some epidemiological studies.

There have been, so far, 9 major epidemiological studies that meet the science of epidemiology. Following there are 10 listed. You will notice Mikalojczyk reported; that was more of a case study of two workplaces; I do not count that as epidemiology.

First, evidence was dismissed on the basis of possibility of chance occurrence. Next, as epidemiological results started to come in beginning in 1984-85, we were treated to another series of delights from the regulatory bodies: positive results and studies were being presented as if they were negative. Negative studies were being presented even though they did not have the statistical power to detect the risk associated with adverse reproductive outcomes and exposure to hazards. There are also very odd things in how people are interpreting the epidemiology. These studies have very mixed and equivocal results. In fact, I would say that you cannot conclude much from them one way or another.

VDT EPIDEMIOLOGICAL REPRODUCTIVE STUDIES

Investigations	Findings
Dr K Kurppa et al Scand. J. Work Environ Health, 1985	Cardiovascular abnormalities Children of part-time VDT workers
Dr A Ericson and Dr B Kallen American Journal of Industrial Medicine, 1986	Significant association between VDT work and birth defects Confounders not separated
Drs B Butler, K Brix Humane Technology, 1986	Slight, not statistically significant increase in spontaneous abortions among VDT workers more than 20 hours
Dr A MacDonald, et al Journal of Occupational Medicine, 1986	Increased risk of spontaneous abortion among VDT workers attributed to recall bias
Dr Mikolajczyk Work with Display Units 1986 Stockholm	Increase in spontaneous abortion among VDT workers under stress Possible link to VLF fields
Dr P Westrholm Tuc, Sweden Work with Display Units 1986 Stockholm	Increased congenital defects (heart) among children of part-time VDT operators
Dr M Goldhaber American Journal of Industrial Medicine, 1988	Increased risk of miscarriages among VDT workers more than 20 hrs/wk Twice as many miscarriages
Drs Bryant and Love International Journal of Epidemiology, 1989	No statistically significant increase in VDT users. But population of heavy users too small
Dr K Kurppa and T Nurminen, Scand. J. Work Environ. Health, 1988	No increased risk of threatened abortions among VDT users
Drs L Brandt and C Vinter Arhus, Denmark, 1990	No reproductive risk increase in one developmental defect Stress as a risk factor

One of the first negative studies was done by Kurppa and Associates in Finland. At the same time as it showed no elevated risk among VDT operators, an anomalous finding was an elevated risk of cardiovascular abnormalities in children of part-time VDT workers. The anomaly is that the dose-response relationship is reversed. Some people have interpreted this as instead of the risk increasing with increasing dose, it seems that the more you have, the better off you are.

In a number of other studies there are similar findings to Kurppa's. They are negative studies; they do not find an elevated risk nor dose-response relationship between the amount of time spent working on a VDT and the risk of miscarriage or birth defect. But they do find anomalous results such as higher incidence of a particular type of birth defect among part-time as opposed to full-time workers. That is seen in a number of studies--in Westrholm's study--increased congenital heart defects; and also in the newer study which is not yet published of Brandt and Vinter, about one cluster at a public institution in Denmark.

There are about four studies which do show an association. But the only one whose authors conclude their results show a definite association is the Goldhaber study recently published in the American Journal of Industrial Medicine. The other studies showing associations as a result of working on VDTs, those of Allison Macdonald, formerly with the Quebec IRSST, and Ericson and Kallen show an elevated risk. But these authors attribute that to possible recall bias, although they have not been able to demonstrate that concretely.

Butler and Brix did find a slight but not statistically significant increase in spontaneous abortions among VDT workers who work more than 20 hours per week. They show a trend which cannot be verified as statistically significant and not possibly due to chance. The problem with that study is that so few operators were heavy users who used VDTs more than 20 hours a week.

The same is true of the study recently conducted by Bryant and Love and published in the International Journal of Epidemiology. They also found no elevated risk of miscarriages among VDT users, whether they used VDTs heavily or not. But the authors admit in that study that the population of heavy users was too small to detect it.

All in all, you have very mixed and anomalous results. What I think you do see is a slight trend to show an association--a weak one. But you cannot use these studies, as the regulatory bodies have, to suggest that they conclusively show that there is not an elevated risk of adverse reproductive outcomes from working on a VDT.

There are two other studies currently ongoing. One being conducted by the National Institute of Occupational Health and Safety in the US is completed but the results are not yet in. I understand that the researchers are now moving into a new phase, a phase which had not been planned in the study. They are planning to actually measure the electromagnetic fields. That is a retrospective study, and as with all retrospective studies, there is always the possibility of recall bias. Because people have experienced an adverse event, they may exaggerate the extent to which they have been exposed to anything that they think might have affected their adverse reproductive outcomes.

The study that should tell us a lot is the one being conducted by Michel Marcus of Mount Sinai Hospital in New York. That is a prospective study which is following women who are yet to be pregnant and monitoring them throughout the next three years. When these women become pregnant, their pregnancy experience and a number of factors including VDT exposure will be looked at.

We had only bits and pieces of knowledge. I would say much of the movement of research in this whole area can be credited to the work of Dr Karel Marha of the Canadian Centre for Occupational Health and Safety. Dr Marha served as a valuable resource person to many people trying to come to grips with this problem. I think his views stimulated a great deal of the research which followed.

Let's take a look at another aspect of this evidence.

VDT VLF RADIATION EXPERIMENTAL STUDIES

INVESTIGATOR	SUBJECT	FREQUENCY	RESULTS
Dr H Mild, et al NBOSH, 1986	Chick Embryos	15 KHz	No significant effects
Mikalojczyk Inst. Occ. Med. Pol Poland, 1986	Rats	T.V.	Fetal deaths Low testicular weight
Tribukait, et al Karolinski Inst, 1986	Mice	20 KHz PMF	Increase in malformations
Frolen, et al Un. Agri. Sciences	Mice	20 KHz PMF	Increase fetal deaths and resorptions
Dr H Mild and I Nordenson, 1987	Amniotic cells	VLF PMF	Chromosome aberrations
Dr M Stuchly Health & Welfare Canada, 1988	Rats	20 KHz PMF	Incomplete bone ossification/blood abnormalities
Frolen, et al Un. Agric. Sciences Sweden, 1989	Mice	20 KHz PMF	Increase in fetal resorptions
Wiley, et al IBM/Ontario Hydro, 1989	Mice	20 KHz PMF	No increase in resorptions, fetal deaths or malformations

What we had to go on to begin with were various studies, many of which were conducted in eastern Europe and the Soviet Union, showing that pulsed electromagnetic fields had more biological effect on both animals and humans than what we call sinusoidal fields. When we began to identify what was actually coming out of a VDT was that the fields, particularly the VLFs, were non-sinusoidal or pulsed. Again the person who pioneered this area was Dr Marha who had raised these issues very early in the game in 1982-83.

Only recently have the ELF coming from VDTs been characterized. The greatest amount of radiant energy from VDTs comes from the horizontal deflection system, VLF, and from the vertical deflection system, ELF, which are pulsed or non-sinusoidal; there is also a powerline frequency from the supply in the unit of 60 cycle fields. We are talking about very complex fields, which are quite high and from which you cannot draw simple conclusions. We had very little direct scientific information. What we knew is what was happening with respect to the utilization of carrier frequencies in microwave research

and looking at pulse carrier frequencies. Marha was one of the people alerting us that this was not a straight one-to-one relationship but a very complicated area in terms of dealing with pulsed magnetic fields and pulsed electromagnetic fields.

Since 1985, eight experimental studies have been conducted. You see Mikolajczyk here too. He did not perform the experiment in the usual way we understand; he turned on a black and white TV and he took some animals and had them run around in a cage. That experiment can be difficult to interpret because he has not given us a great deal of information on the research protocol nor can we be sure that the animals were not exposed to something other than VLF or ELF frequencies from the TV.

Most of the other studies listed are more controlled; they have isolated the particular agent of exposure and controlled the conditions under which exposure took place to eliminate factors which might confound and upset the results. Only two studies of the eight have not produced a biological effect. The first study to come out, by Tribukait et al from the Karolinska Institute, was the groundbreaking one. It was the first time one had actually exposed mice to the particular type of VDT pulsed field, 20 KHz range. These were magnetic fields. They did see an increase in external malformations among the mice exposed.

From there, the Swedish government funded four of them to see if Frolen could replicate the study conducted at the Karolinska Institute; and indeed he did--but with different results. Instead of an increase in malformations, he saw an increase in fetal deaths and resorptions. He later replicated that study again and again got some different results. What he saw was an increase in fetal resorptions but no increase in fetal deaths or increase in fetal malformations. In the view of Frolen and many of his colleagues, there are biological effects, but they are different ones. There is biological activity going on. The mechanism is very difficult to determine. One variation in the studies was delayed exposures in some of the animals in groups of his controls. Instead of exposing them right at the beginning of pregnancy, he exposed some in the later period of pregnancy. He concludes that the earlier in the pregnancy one is exposed, the more likely the fetus is to be affected adversely. That was also seen in several other related studies, not on VLF, but on ELF, particularly the studies by Alexander Martin.

Mild, who had not found any effects on chick embryos, did, with his colleague Nordenson, find that when they exposed human amniotic cells to VLF pulsed magnetic fields they did see a statistically significant increase in chromosome aberrations. This means that these fields could possibly have genetic effects.

Stuchly and her colleagues used rats in their study in Canada. They used a different animal and varied the parameters from the other studies. They did not follow the same protocol. They found incomplete bone ossification in some of the animals, which they dismissed as "normal noise," but they did find certain blood abnormalities in the exposed fetuses and animals that were exposed. One of the conclusions is that some of the blood abnormalities might be due to the toxic effects of the magnetic field itself. Stuchly is not one of the supporters of the possibility of risk of low level exposure to electromagnetic fields, yet even her research shows effects.

Frolen also replicated the study he had done in 1987. Wiley and associates, funded by IBM and Ontario Hydro, conducted a very tight study in terms of protocol and controls and found no increase in resorptions or miscarriages or spontaneous abortions in animals, fetal deaths or malformations. How you interpet that, I do not know.

I take great delight in criticizing scientists who take money from corporations and conduct studies. Our experience with this has not been good. All I have to do is draw your attention to the conflicting asbestos studies done by Corbett Macdonald for example, for the Asbestos Mining Institute which found no increased risk from exposure to asbestos. Selikoff studied the same population in a different and more correct way, given the long latency period, and found an elevated risk. So, it depends on how you do things.

What has been overlooked for the last while is the ELF emissions from VDTs. There was great debate as to whether these were sinusoidal or non-sinusoidal. It has been empirically established and finally, I think Maria Stuchly agrees after having seen the data on this and the methods used, that these are non-sinusoidal at least. Some of these field strengths are much stronger than the VLF fields measured from VDTs.

It is alarming that in the henhouse project, six independent laboratories found that there was an increase in abnormalities in chick embryos exposed to very low levels of pulsed magnetic fields. That was also replicated by Martin. Martin participated in that project and later conducted another independent study which confirmed that effect. At the same time, he did what was similarly done by Frolen in the VLF studies where he varied, not the duration of exposure, but the point at which exposure started. He found that the earlier the embryos were exposed, the more vulnerable they were to adverse effects.

There certainly have been other developments. There definitely have been great advances in measuring techniques, particularly of electromagnetic fields. When they first investigated the cluster at the Toronto Star in 1981, they tried to measure for microwaves and radiofrequencies. Not only that, they were measuring in power densities and at these low frequencies, it makes no sense to measure this way. Yet that is what was done until recently. Measuring techniques have improved. New portable meters have been developed. And there is a trend for companies to introduce shielding of VDTs to try to eliminate the pulsed magnetic fields.

The animal evidence does not say that VDT radiation causes adverse reproductive outcomes. It indicates only that it is possible that these radiations can upset fetal development in humans. That's all. Again, with respect to the epidemiological studies, very little conclusion can be drawn one way or another.

Just looking at the etiological factors, to draw the conclusion that VDTs do not pose a risk is not soundly scientifically based. Saying that there is no evidence that VDTs can produce reproductive risk is absurd. There is insufficient evidence, but there is not no evidence. But there will be problems. In terms of determining what the etiological factors are, we have some experimental studies with the problem of extrapolating from animals to man. Other factors could possibly explain what is responsible for the results such as stress or other ergonomic factors. There will be problems with future studies too, problems in determining exposures. In the Kurppa study it is obvious that the exposures were misclassified. And, of course, the other problem is confounding factors, whether lifestyle problems, which the research has not separated out, and factors which may co-vary with work on VDTs. You have a period of scientific uncertainty and sometimes there is a social conflict between increasing worker protection and establishing scientific certainty. The real question facing us now is what do you do in the face of scientific uncertainty?

To delay regulatory action and then to find that there is some quantifiable risk could be catastrophic. In North America alone, we are talking about over 30 million people using VDTs most of whom are women. And we know it is possible that these fields may also cause genetic effects and are even currently being associated with cancer.

QUESTIONS AND DISCUSSION

Kathleen Henderson - Manitoba Telephone System

We have 5,600 employees and an inventory of 4,000 VDTs. We have ergonomic guidelines, we are looking at stress and a design team is looking at the nature of work. What would you suggest for an average work station where you might use a VDT anywhere from two to six hours a day?

Bob DiMatteo

Are you talking specifically on the radiation question?

Kathleen Henderson

If there is a radiation question.

Bob DiMatteo

There is a radiation question, the question is what do you do in the face of the scientific uncertainty?

Ideally, these sets should be shielded and certainly monitored. The task of shielding electrical fields is not that difficult. When we talk about magnetic fields, we are talking about a real problem. I think it will finally be addressed by the manufacturers themselves, as IBM is doing right now by manufacturing a low magnetic field terminal. As well, by introducing alternative cold screen technologies, such as liquid crystal displays, being careful that you take care of the little fluorescent light in the back which also gives out an ELF field.

Breaks will help with the ergonomic stresses and the psychosocial stresses involved in the work. Decreasing the amount of time spent on VDTs makes ultimate good sense from the point of view of ergonomics and stress as well as the possible radiation hazard. The sources of radiation tend to be highly localized. The display terminals can be located so that people are not directly exposed to those areas where the source is the strongest, mainly the sides and the back of the set. One can also look at increasing the distance from the terminals in that the fields diminish quite dramatically the further away you are from the sets. Those are some of the things that can be done.

Maurice Bitran - Ontario Ministry of Labour

In spite of our research, a consistent body of scientific data that shows that radiation from VDTs produce health effects is lacking. There are some mixed results.

You have to give adequate weight to the results of different scientific studies. There are studies that have been properly designed, protocols that have been subject to peer review, results that have been published in peer-reviewed journals and there are other studies that have not been done so rigorously. One of the most rigorous animal studies to date is the one by the University of Toronto and Ontario Hydro that was so lightly dismissed by Mr DiMatteo.

It is important in a scientific process to base results on solid studies on a body of data that is consistent. I am not saying that the research conclusively shows that there are no effects. We are open to new research and new results on this subject.

The results so far have been assessed by independent bodies that meet under the auspices of the World Health Organization like the IRPA Committee which concludes that, based on current biomedical knowledge, there are no health hazards associated with radiation or fields from VDTs. Thus, there is no scientific basis to justify shielding or radiation monitoring. However, since a large number of people are involved in work with VDTs, it is important that further knowledge be obtained.

Lillian Vine

At several of our workshops on different topics, our participants have concluded that when there is uncertainty and there are clashing studies, the best path might be prudence.

Maurice Bitran

Because of the nature of the dose response relationship, I asked a dentist if he would advise shielding of VDTs. He said no, you may be pushing people into an intensity window.

Bob DiMatteo

What am I supposed to do because an international body has said that there is no evidence when there is, even though it might be insufficient evidence? I think it would be more responsible for them to say as scientists that they do not have sufficient data to say one way or another. But to say there is no evidence whatsoever would be scientifically wrong.

Kevin Freier - Eveready Canada Inc

I am not sure I understand the studies and the physiological effect. Does it actually affect the fetus itself by passing through the mother? Or is it affecting the mother who passes it onto the child?

Bob DiMatteo

That is a good question. Is it a direct effect on the germ cells, a direct effect on the fetus or is something happening, as a result of exposure, to the parent, hormonally perhaps, that could somehow upset fetal development? No one knows. If we do not dismiss these questions, we may be able to find some out things.

For example, the Frolen study indicating higher risk from exposures earlier in the pregnancy may give us some clues; the Karolinska study with a different species of mice showing increased incidence of external malformations rather than internal malformations may give us some clue.

Many an occupational health problem that has been minimized by the establishment, by the regulatory bodies, and by the industry has turned out to be a disaster.

When I hear that you get more radiation from your bed partner than you get from a VDT, I am not sure whether people are trying to encourage my abstinence or trying to assuage my fears. This sort of bureaucratic nonsense obstructs us from getting to the kinds of scientific questions we should be asking and to which we should be endeavouring to find answers.

Stuart Franck - Peel Board of Education

I am with a firm of over 10,000 employees and over 100,000 students, most of whom use VDTs occasionally. We are very concerned about the VDT issue. Often a lot of our energies are spent on the guesses, the maximizing of concerns, sometimes needlessly. What would it take to put the issue at rest, this Mount Sinai study? We are tracking people over three or five years and showing any type of health implications.

Bob DiMatteo

I think certainly the Mount Sinai study may hold, at least in terms of study design, evidence to have more confidence in. The science of epidemiology is a very imperfect science. Even under the best of conditions. I do not think one more animal study is going to put the issue to rest.

I think we have to take a look at what our values are in this society and whether we value human health more than we do the bottom line. I think that we have to start looking at this from a public health point of view and begin to take a precautionary approach. I think that it really makes ultimate good sense to try to err on the side of safety. I think it is time to talk about what we can do, whether we are talking about VDTs or powerlines. What kinds of things can we do? That takes some intelligent, not altogether scientific, but sound social policy analysis. In other words, it is no longer just a scientific question, but one of values.

Margaret Abela - Workers' Health and Safety Centre

I feel if there is any error to be made, I would rather it be on the safe side. We would like to feel that we could protect pregnant women. If you have shielding in front of the screen and some shielding inside, is that sufficient to protect the person from that radiation? I am glad to hear that IBM is now producing VDTs with shielding.

Bob DiMatteo

The thing that makes this whole question difficult is we do not know what levels. There are such complexities! You find power windows and even frequency windows so it becomes difficult to give assurance that shielding will do the trick, but at least it is something. I think it is best handled at the manufacturing level. What we need is to regulate. But at what level? What is the standard of exposure?

We are not going to be able to deal with it in an immediate way; we have to look at it in a programmatic way. We have to look at alternate technologies. If people intend to become pregnant, they should announce that to their employer and a civilized and responsible employer will get and use cold screen technology. I am not trying to advertise and I have no interest in the company, but there is a company called Safe Computing which makes an LCD screen which is entirely shielded; even the back-lighting ELF emissions are shielded. Maybe it is overkill, but it is one alternative. Do not wear lead aprons; that is probably going to create even more of a problem.

Denis Brown - Saskatchewan Department of Human Resources, Labour and Employment

When you are a regulator you are faced with the position that you cannot regulate until you have some scientific facts to regulate on. What we had was a battery of concerns; we were worried about the clusters. We did not know the origin any more than you did. But we had to do something to answer immediate concerns.

We have always tried to present the scientific facts. We have recognized that better terminals are coming out. We have given information on measurements. But we have been faced with people often being blinded by looking at only one potential source of problem.

Our personal feeling has been that stress and ergonomics are two of the most important factors in these pregnancy clusters. If you go back in history, tribe women were gathering insects and nuts, stretching and bending; they were not sitting at a terminal 8 hours a day. Generally, they had healthy kids. If you sit in front of a terminal with constricted circulation 8 hours a day and do not move around, you have got a problem. Now somebody blames radiation. No attention is paid to what could be the more urgent problem.

My impression is that many of the clusters came in the early days. Middle-aged workers who had spent years and years working on conventional typewriters were suddenly put onto a terminal. They were frightened to death; they were not sure they would be able to hold their jobs. Young people were coming out of school who were familiar with the terminals. The stress was tremendous. We had no facts on which we could regulate. We could recognize a need for improved terminal design, safety was a concern, but all we could do was to try making the information available. I honestly believe that most of us did try to do that.

Bob DiMatteo

I absolutely agree. What I am not seeing is a response on the part of regulatory bodies to regulate the stress factor and the ergonomic factor. No one has done that in this country or in the United States. The Swedes and the Norwegians and the Scandinavians have always done that. Mainly because 80 to 90 per cent of the workforce is organized, they bargain on a central basis and have a lot of clout.

If you are saying that stress could be a factor, then regulate the stress, limit the amount of time people have to work in these electronic sweatshops.

Denis Brown

We do have regulations in Saskatchewan, though you might not be satisfied with them.

POWERLINES - CANCERS AND OTHER CONCERNS

Lillian Vine

Jan Deadman comes from McGill University from which he holds his Master of Science degree in Occupational Health. He has worked in occupational hygiene since 1978, initially at the Johns Manville chrysotile asbestos mine in Asbestos, Quebec, then at the Community Health Department of Laval, at the Institut de recherche en santé et en sécurité du travail, and currently at McGill University.

He is presently involved in two studies of cancer in relation to electromagnetic fields exposure. He is responsible for the exposure assessment components of the joint Canada-France Occupational Study of EMF Exposure and Cancer, and the Canadian study of EMF and childhood leukemia. He is also a consultant to the United States National Cancer Institute Study of EMF exposure and childhood leukemia. He teaches an annual Master's level course in basic occupational hygiene. Among other activities, from 1985 to 1987 he was Chief Editor of the French language health and safety magazine, Travail et Santé, which he helped establish in 1985.

Jan Deadman

I will be talking about 60-Hz or power frequency, electric and magnetic fields and transient fields, which is electronic noise associated with the distribution and use of 60-Hz electric and magnetic fields. I will establish the background on electromagnetic fields--what they are and how they interact with the body, what some typical sources and levels of exposure are, how exposures are measured, where these exposures come from, and how they interact with a living system. I will do this based on experimental studies and I will also review the epidemiological studies.

When electricity was first introduced on a large scale, around 1883, it was thought that its use for lighting was in no way harmful to health nor would it affect the soundness of sleep. We have come a little further since then. The growth in the past 50 years of the use of 50/60 Hz magnetic fields is exposing all of us in developed countries to a virtual sea of man-made extremely low frequency electromagnetic fields (ELF-EMF). Frequencies other than 50/60 Hz are also used, such as in commercial aircraft. The generators on aircraft run at 400 Hz and above and can result in significant exposures to the staff on air flights. Electricity is not a substance foreign to the body. It is not as if we were exposed to a chemical agent or to noise. Electricity is part of the human body; we function on electricity; we are electric beings. For example, when we walk, the bones in our legs generate electric currents by the sheer pressure of walking.

The electric field (E) is caused by voltage on a wire, the field exists in the air around it. Figure 5 gives an example of an electric field produced by a lamp.

The lamp on top is plugged into an electric outlet and there is an electric field on the wire. There is no current flowing but the electric field is there because you have established an electric potential. As soon as the lamp is turned on, there is then an electric and a magnetic field.

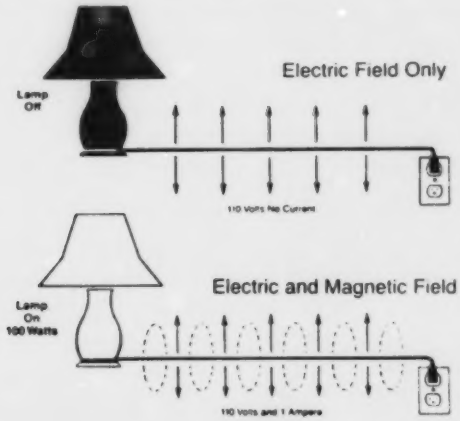


Figure 5

The field strengths for electric fields are expressed in units of volts per metre (V/m). Electric field lines emanate from the conductors and are affected by conductive objects. The electric lines come in and are concentrated on the body.

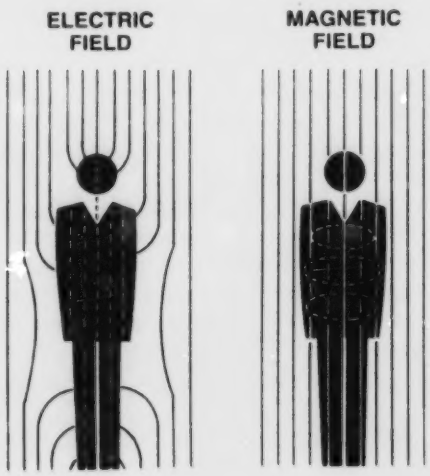


Figure 6

The figure on the left shows a person standing under a high voltage transmission line and the electric field lines are pretty much vertical. They are being localized on the surface of the body; the body is drawing the lines in. You have very high fields on the

top of your head. These fields would be enhanced and you would get something in the order of 150-200 times enhancement on the top of your head. At chest level, the average enhancement would be 2-1/2 times what the free field is if the person is not standing there. The two notions are important--the perturbed field (the field you are measuring on the body) and the unperturbed field (the field present when no one is standing there). Electric fields produce local fields on the body and these local fields again produce electric currents inside the body.

The magnetic field is created whenever there is current flowing in a wire. The units of tesla (T), usually as microtesla (uT) are used to express these magnetic field levels. You will also see gauss (G) used. If you ever see figures in milligauss (mG), which is the usual unit, move the decimal one point to the left and you will get microtesla. These are the two units most often used.

Magnetic fields pass through most common objects; they are difficult to shield. They too induce electric fields in the body and circulating currents inside the body. With the figure standing under the magnetic field, the circulating currents are shown as loops inside the body. These currents are not conducted to ground. Magnetic fields will induce circulating currents; electric fields will induce currents that conduct through to the ground.

The third type of field is referred to as high-frequency transient fields (HFT). These are fields in the frequency range of 5 to 20 MHz. They are in the radio frequency range and they are extremely rapid electromagnetic disturbances, such as arcing from electric motors, switches or power surges radiated by wiring. Wiring that is designed to transmit and distribute electric current at 60 Hz is much more efficient at distributing this electromagnetic noise than it is at distributing the current. These fields have superior coupling to the human body in that they induce proportionally higher levels of current than do the 50 to 60 Hz fields. We use the 5 to 20 MHz frequency band as a way of measuring these fields.

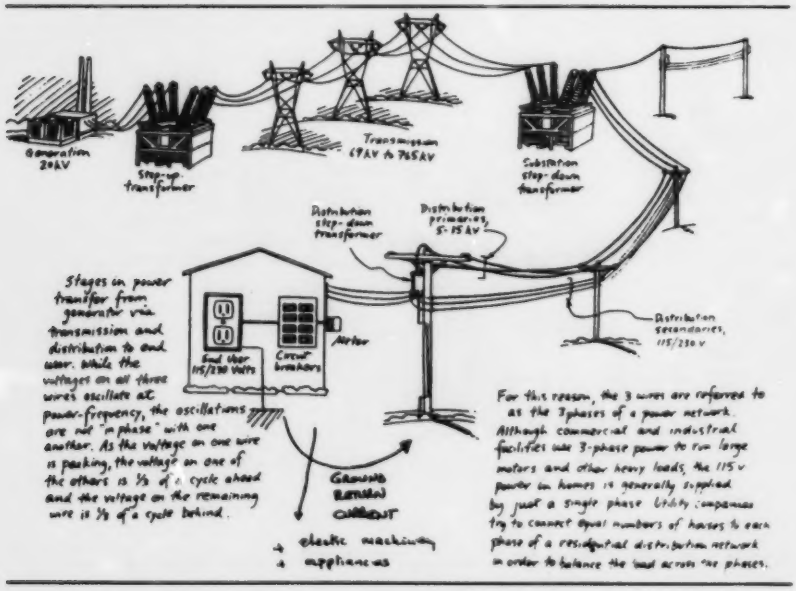

Generation 20kV
Step-up transformer
Transmission 69kV to 765kV
Substation step-down transformer
Distribution step-down transformer
Distribution primaries, 5-15 kV
Distribution secondaries, 115/230 V
Stages in power transfer from generator via transmission and distribution to end user. While the voltages on all three wires oscillate at power-frequency, the oscillations are not "in phase" with one another. As the voltage on one wire is peaking, the voltage on one of the others is 1/3 of a cycle ahead and the voltage on the remaining wire is 1/3 of a cycle behind.
and their 115/230 Volts
Circuit breakers
Meter
Ground (Earth) CIRCUIT
electric machinery
appliances
For this reason, the 3 wires are referred to as the 3 phases of a power network. Although commercial and industrial facilities use 3-phase power to run large motors and other heavy loads, the 115 v power in homes is generally supplied by just a single phase. Utility companies try to connect equal numbers of houses to each phase of a residential distribution network in order to balance the load across the phases.

Figure 7

The electric power system that is used to generate and distribute electricity starts from the generation, either by thermal, nuclear or hydroelectric generation, through step-up transformers to the transmission lines. The transmission lines have very high electric field levels since the voltages are higher; the current is not excessively high because it is easier to transport high voltages than high current. The transmission lines go to substations where voltage is stepped-down to the distribution primaries and secondaries, which are the standard poles you see in the streets or buried underground. Lower electric fields are associated with these distribution lines because the voltages are lower, but larger numbers of people can be exposed because of the proximity of the lines to homes. An important third source of fields that is not often considered is returning ground current. Once electricity is inside your house, a significant amount of the electric current returns through the ground to the electric distribution network. Other sources inside the home, once the power is used, are electrical machinery and appliances.

Exposures to 60 Hz fields are almost entirely man-made. There is continuous exposure from the electrical distribution system. Strong occasional fields can result from appliances; electric blankets and electric razors are two of the worst offenders but these are very high fields up close which drop off usually to about less than 0.1 uT at a distance greater than 1 metre. The earth's natural geomagnetic field does have a 60 Hz component, but it is extremely low (about 10^{-12} T).

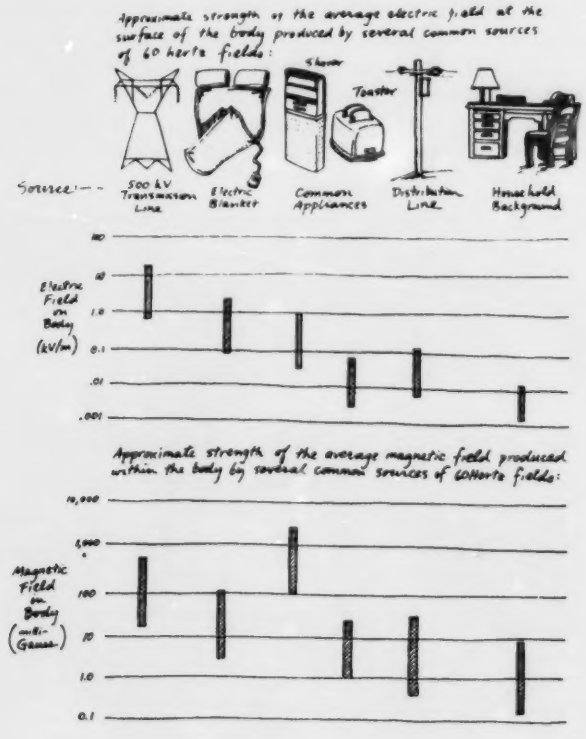


Figure 8

The top graph shows electric fields and the bottom graph shows magnetic fields. The highest exposure you could encounter for an electric field would be underneath a transmission line, but you would not stand there too often. An electric blanket is the most significant source of domestic exposure for electric fields. For magnetic fields you can see that the electric razor is the highest magnetic field exposure you would run into.

It is uncertain at the moment what is a meaningful parameter of exposure. We are measuring electric fields on the surface of the body, the magnetic field at the location where the dosimeter is worn, but what we are trying to get at is a measure of the current induced inside the body. Unfortunately, we cannot easily measure that current so we have to measure a proxy of it. The important thing is that if we measure the same thing on everyone, we will have a comparable unit from study to study and person to person.

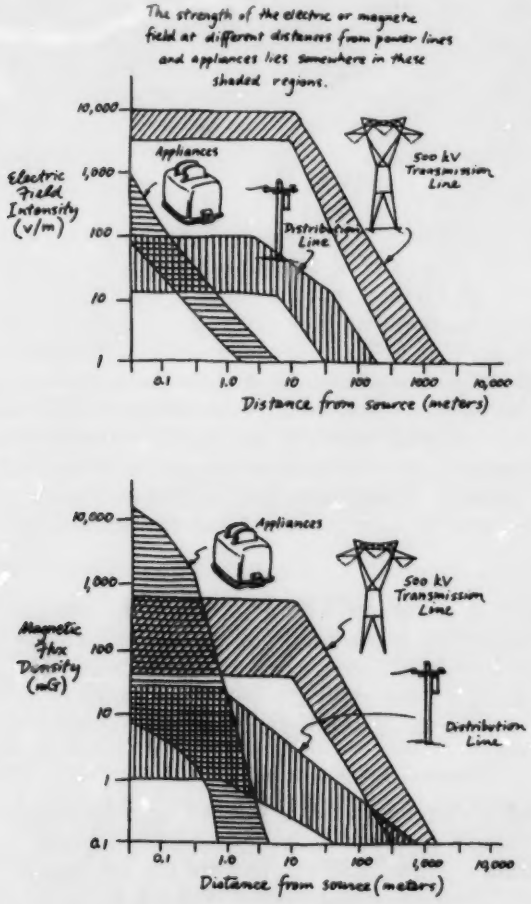


Figure 9

Figure 9 shows that the strength of electric or magnetic fields at different distances from power lines and appliances lies somewhere between the shaded regions. On the top graph, if you follow the shaded region for the transmission line, you will see that transmission line and distribution line electric fields drop off much more slowly than do electric fields from appliances. On the bottom graph, the vertical axis is magnetic flux density and the horizontal axis is the distance from the source. So, for instance, the toaster will produce fields that drop off extremely quickly whereas the distribution and transmission lines will continue to expose you even if you are living fairly far away from the line. There is also the duration of exposure to be taken into consideration. Appliances expose you to a very short duration exposure; transmission lines and distribution lines to a much longer duration one.

Fields are measured using a coil in which the magnetic field lines passing through the coil produce current. The current trend toward measuring exposures is to use smaller devices, such as a dosimeter which can be worn by a worker and which monitors exposure once a minute or faster over a period of several days up to three weeks or more. Electric fields, magnetic fields and transient fields are measured. The information is dumped from the dosimeter into a computer where the exposure history can be reconstructed and average exposures calculated. This gives us a handy means of measuring individual exposures, not just what the field level was at a given point in time. This will also give us truer estimates of what the average exposures are over time. This dosimeter will be used in the Canadian childhood leukemia study and is also being used in the joint Canada-France ELF utility study.

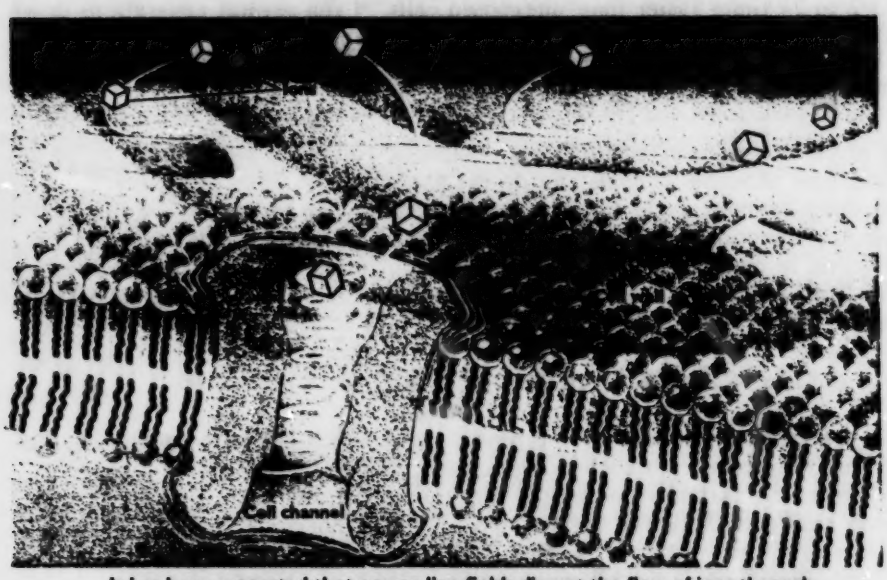
It has been said that the current state of ELF research puts us about where we were with ionizing radiation in 1926. The effects of low-level ionizing radiation are still being debated and are still controversial. This should serve as a warning to us that with ELF, we are dealing with an area of science that is at a very early stage of development.

Acute effects of exposure to very intense ELF fields have been known for many years, field perception, for example. If you stand underneath a high voltage transmission line and the ground is wet and you put your arm up, you will feel the hairs on your arm vibrating from the electric fields. You will have annoyance due to spark discharges. If you park your car or truck under a transmission line, it accumulates a charge and acts as a capacitor. If you touch the car, you are grounded and the accumulated charge on the car will discharge into you.

Annoyance and muscular tetanus can occur with a sufficient current (touching ungrounded conducting objects)--the muscles are locked and you cannot move your hands. Pacemakers have been interfered with by magnetic fields. And phosphenes can be generated by high magnetic fields. I will not discuss these effects here. They result from high and well-known intensities and the standards and regulations that do exist have been set up to limit these effects.

How do ELF E (electric) and B (magnetic) fields interact with living systems? We know that they are not energetic enough to break chemical bonds as ionizing radiation is. We know that they do not generate significant heat, they are not mutagenic. It is unclear if there are any interactions with the immune system, but we know that the initial physical interaction is by the induction of electric fields and currents on cells and tissues. Secondary events may then occur that involve biochemical and structural alterations at the cellular and subcellular levels.

There is substantial evidence in cellular studies that current circulating around the surface of the cell can alter the cell surface membrane. The most well-known theory is called the Ion cyclotron resonance theory (Liboff, Adey). Changes in calcium ions which flow across cell boundaries can be induced at the right combination of alternating fields and static fields, such as the earth's magnetic field. The significance of this is that ions are chemical messengers that influence many basic cellular functions from reproduction to respiration.



It has been suggested that power-line fields disrupt the flow of ions through channels in cell membranes. Fields of certain frequencies may resonate with the natural frequencies of the moving ions, speeding their exit from the cell.

Figure 10

Figure 10 shows the cell wall and cell channel. You have a cyclotron of an ion, in this case calcium. Calcium and all other ions are exchanged and pass through cell channels at a specific frequency determined by the ion and by the cell channel, in this case about 16 Hz. If you then expose this cell to 16 Hz AC field with the right combination of a DC magnetic field, the ions start moving out of the cell membrane at a faster than normal rate. So the cells lose calcium much faster than they should. This was tested by Liboff who did some work with rats and looked at the efflux of lithium from the brain. At the right combination of these two fields, the rats went completely crazy. They lost so much lithium from their brains that they exhibited all the symptoms of manic depression. As soon as either the DC or the AC field was turned off, everything fell back to normal. This happens at 16 Hz. There are studies going on into calcium loss in workers exposed to 50/60 Hz fields, but I am not aware of any clear conclusions so far.

There has also been some ground-breaking work showing disturbances in DNA synthesis. Liboff exposed some healthy and some cancerous lymph cells to ELF fields and found that both the healthy and the malignant cells started to produce more DNA, which to him was a sign that these cells were getting ready to divide. Here is evidence that perhaps these ELF fields act as promoters of carcinogenesis by helping cancerous cells start growing more rapidly.

Phillips, who exposed cancer colony cells (colon cancer, leukemia and breast cancer cells) to various combinations of electric and magnetic fields, found that these cells proliferated 2 to 24 times faster than unexposed cells. Even several generations down the road, the descendants of these cells that were not exposed still showed more resistance to natural killer cells, the white blood cells in the body. Here is potential evidence that these fields could be promoting cancer.

One of the more important effects of electromagnetic fields has been shown to be on biological rhythms in whole animals and on the endocrine system. The circadian rhythm governs our daily 24-hour cycle which tells us when to sleep, when to wake up and affects our physiological functions. It is now well established that ELF fields will alter the circadian rhythm in mammals. Disruptions of the circadian rhythm have been associated with immune dysfunctions, hypertension, affective disorders (SAD - seasonal affective disorder), shift work fatigue, psychoses, and alterations in cell-division cycles which can lead to mutagenesis and oncogenesis. People who study biological rhythms suspect a link between the loss of timing of cellular events and cancer promotion.

Melatonin is a hormone produced by the pineal gland which has its circadian rhythm affected by environmental cues such as light, food, and so on. Its production is normally triggered by darkness, increasing throughout the day until it peaks at night. This hormone has been called the brain's "cancer-killing hormone" and has been given to cancer patients to inhibit malignant growth. In experimental studies, two malignant neoplasms, melanoma and breast cancer, have been inhibited by melatonin during the promotion phase. It does not inhibit the initiation of the cancer cells, but once they start to grow the use of melatonin will inhibit the growth of these two types of cells. It has also been noticed that in people with colon cancers, ovarian cancers and some breast cancers, the melatonin rhythm has been perturbed. Whether that was associated with the cancer or whether it was part of the causal sequence leading up to the cancer is not clear.

Disruptions in melatonin circadian rhythm have been associated with major depression. One of the studies has linked suicide with exposure to magnetic field. In rats, for instance, after three weeks of exposure to the right level of electromagnetic fields, the animals show a reduction in nighttime melatonin production. In squirrel monkeys, the circadian rhythm has been lengthened by exposure to these fields.

To summarize the experimental studies, ELF electric and magnetic fields can affect the biological functions of cells and tissues through their induction of potentials on cell membranes. These effects, nonetheless, are dependent on the frequency, the waveform, the strength and the time of exposure. There appear to be "window" effects; in other words, low level exposures do not appear to induce the effect; medium level will produce it; above that level, the effect disappears. There is no clear exposure/response relationship.

CCOHS/CCHST

In epidemiological studies of the health of people exposed to electromagnetic fields, the ground-breaking work of Russian researchers in 1972, such as Asanova and Rakov, suggested that there was a link between electric fields, electric spark discharges and reported fatigue, headache and increased excitability in electrical substation workers. This sparked Ontario Hydro and a Swedish researcher, Knave, in 1979 to look at clinical symptoms among electric utility tradesmen over a 5 to 10 year period. They did not find any clinical symptoms at that time.

In 1977, the New York State Public Service Commission conducted hearings on a proposed 765 kV line that was to pass through New York State. At that time, two researchers, Robert Becker and Andrew Marina, testified that they had exposed rats to fields similar to those that would be found near a 765 kV line and found changes in blood proteins and a reduction in body weight. The offspring of these rats were stunted and had higher mortality rates. These two researchers felt that similar effects were likely to appear in people living near the proposed lines. Despite this evidence, the Commission approved the line, but set up a $5 million research program, the New York Power Lines Project (NYPL).

In 1979, the landmark study by Nancy Wertheimer and Ed Leever sparked things off. Nancy Wertheimer was not looking for any particular association; she was taking a shotgun approach to try to explain the childhood leukemias she was observing. She ended up proving statistically that there was a link between childhood leukemia and other cancers and the proximity of high-current power distribution lines, estimated at a 2-fold increase risk.

An attempt to replicate this study in 1980 in Rhode Island showed no association between childhood leukemia and power lines. In 1980 again, a Swedish study by Tomenius found childhood cancers twice as often in homes near 200 kV transmission lines. In 1981, Perry found an association between power frequency magnetic fields and suicide. In 1988, he looked at the association between clinical depression, heart disease and the proximity of residence to power cables within apartment blocks. He found that those with apartments closer to the cables tended to have higher incidence of depression, heart disease, and so on.

In 1982, Wertheimer and Leeper came back again with an adult cancer study showing higher cancer risks for adults living near high-current power lines, with a relative risk of about 1.4.

In 1982, Sam Milham performed a mortality study which looked at different occupations to try to explain what was causing brain cancers and leukemias and found that there were 10 occupations with assumed higher exposures to ELF electric and magnetic fields that showed a statistically significant 1.4 times increase in deaths due to leukemia.

In 1983 in Sweden, wives of workers in high voltage switchyards were found to have abnormal pregnancy outcomes and congenital malformations. This was thought to be due to possible chromosomal aberrations from sparks, spark discharges of transient fields, and electrical fields in the substations.

In 1985, two studies in the UK found no association between childhood cancer and power lines and adult cancer and power lines. In 1985, Lin found that jobs in which EM field exposures were likely were noted more frequently among victims of primary brain tumours when compared to controls.

In 1986, David Savitz, a researcher at the University of North Carolina, essentially confirmed Wertheimer's 1970 childhood cancer study. He looked at childhood leukemia, the type of distribution lines near the cases and control homes and characterized them, as had Wertheimer and Leeper, according to their current configuration, this being a proxy for the magnetic field level. So the higher the current configuration, the higher the magnetic field. He found about a 1.5 times increased risk of childhood leukemia compared to those living near low-current lines. The NYPL project extended the findings of Savitz's study and they estimated that anywhere from 10% to 15% of all childhood cancer might be due to power-line fields. The level at which David Savitz distinguished between his cases and controls was about 0.3 uT, or 3 mG.

In 1986, Stevens in Seattle looked at adults and found no association between acute nonlymphocytic leukemia (ANL) and power lines. And Wertheimer and Leeper in 1986 looked at electric blanket or heated waterbed use as a proxy for electric and magnetic fields at or near the time of conception. They showed that there was prolonged gestation and relatively low birth weight for their gestational age in the offspring.

In 1987, David Savitz and Eugenia Calle reviewed eleven occupational studies and estimated that there was a 1.2 to 1.5 times increased risk for workers in 12 electrical occupations to have died from various types of leukemia compared to other occupations.

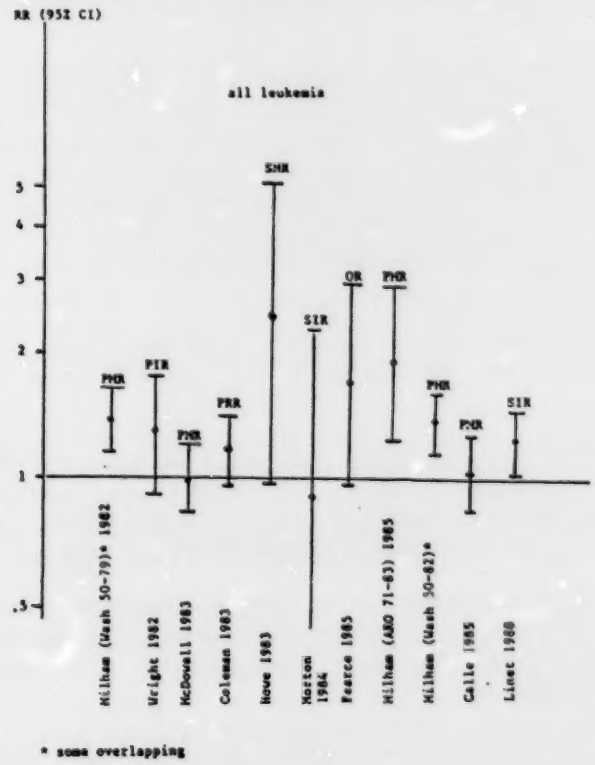


Figure 11 - Leukemia risks among electrical workers

Figure 11 gives the estimates of relative leukemia risks among electrical workers. The level of 1 would be no risk; the points are the risk estimates from the epidemiological studies with the bars being the 95% confidence intervals. If there was in effect no risk, you would expect to see an equal number of positive and negative studies, but there is a definite trend of these studies to the positive side of 1.

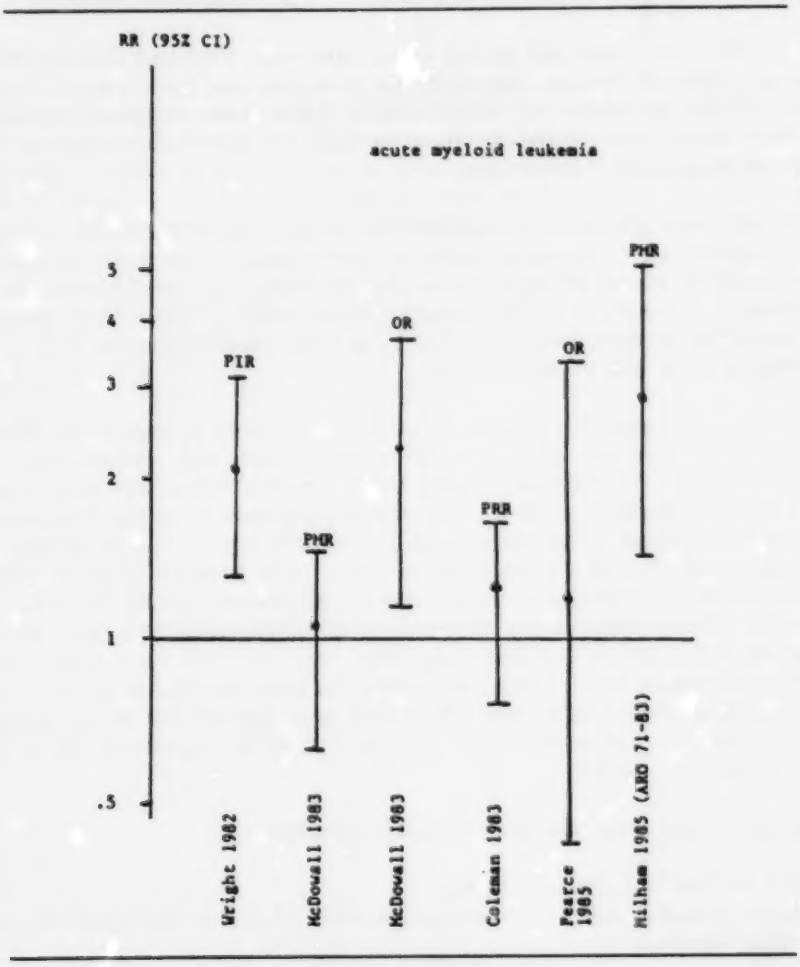


Figure 12

Occupational studies on acute myeloid leukemia show a similar trend with all relative risks being pretty much above 1 or close to it.

In 1989, Genevieve Matanoski conducted a case-control study of leukemia risk among telephone workers at the New York Telephone Company. Her preliminary results showed no evidence of increased risk of leukemia among these workers. She then did a cohort study to identify incident cases. She looked at 50,582 active male employees over a 5-year period. She then compared the cancer rates within this group with cancer rates in the general population and found no excess risk. However, when she compared the cancer rates

of the exposed workers to the cancer rates of unexposed workers within the utility company, she found significant risk levels. The cable splicers, the most highly exposed group, had statistically significant risks--1.8 for all cancer; 7.0 for leukemia; 3.6 for lymphoma. She also found an elevated risk of breast cancer among male central office technicians. Checking into the possible exposures, she found that many electro-mechanical switches were used in the central office which would have led to a large exposure to transient electromagnetic fields.

David Savitz in 1990 went back and looked at his data from 1986 and found that there was an association of childhood cancers, especially for leukemia and brain cancer, with the prenatal use of electric blankets. As the duration of blanket use increased, the odds ratio of the risk estimate also increased. Here we have the first direct evidence of exposure-response relationship in humans.

In 1990, ELF fields were shown to contribute little if any risk of testicular cancer among electric blanket users. A recent study by Pierre Band of the Cancer Control Agency of Vancouver found an excess of brain cancer, rectal cancer, non-melanoma skin cancer and Hodgkin's Disease in a cohort of 913 Canadian Airlines pilots. These pilots are exposed among other radiation, to electromagnetic fields from the planes' generators at frequencies ranging from 400 to several GHz.

The human studies are suggestive of weak behavioural, neurophysiological or neurochemical effects. There is some evidence of an association with suicide and reproductive effects, but it is not very strong. The studies are plagued by small numbers and poor exposure assessment. There is suggestive evidence that chronic exposure to power-frequency fields may promote certain cancers. The cancer type in excess is not always the same; occupations with excess risk vary from study to study. The strength of the association could be characterized as moderate to weak: 1.18 for all leukemia; 1.46 for acute myeloid leukemia. Three cancer types have shown up across several studies: acute myeloid leukemia, brain cancer and skin melanoma. But the studies are plagued by weaknesses of small sample sizes, exposures having not been assessed or indirectly or poorly assessed, and confounding factors which may have contributed to the cancer. No causal association has yet been established. But the studies are suggestive and raise questions that cannot be ignored.

The following studies are some that are currently underway:

Canada: McGill University (Theriault et al)
Joint Canada-France epidemiological study of cancer and EMF exposure in utility workers
Cancer Control Agency of BC (Gallagher et al)
Childhood leukemia and low-frequency electromagnetic radiation

USA: University of Southern California (Bowman et al)
Childhood leukemia and residential EM fields
Brain tumours in children and exposure to magnetic fields
Electromagnetic fields exposure and cancer among electric utility workers
National Cancer Institute (Linet et al)
Childhood leukemia and exposure to ELF fields
Sweden (Knave, Lind)
Prospective study of electric utility workers exposed to ELF fields

QUESTIONS AND DISCUSSION

Ray Kosan - Ontario Hospital Association

You mentioned confounding factors being present. Surely with electrical utility workers who work with industrial solvents, some of which are known to be carcinogenic, there must have been some documentation on the degree of exposure if there was exposure.

Jan Deadman

It has been poorly documented. In our case, Hydro Quebec, there was one industrial hygienist for the whole company. In France, since 1970 they have been actively documenting exposures to other chemical agents. It varies according to country and according to practice. For this study we are assessing exposures, not just to electric magnetic fields, but also to about 60 or 70 other potential agents that may be associated with these cancers.

PRESENTATIONS

Introduction to Ionizing Radiation
Bhawani Pathak, Canadian Centre for Occupational Health and Safety

Radon - A Silent Killer?
Denis Brown, Saskatchewan Department of Human Resources, Labour and Employment

Nuclear Industry - Hazards and Benefits
Gerry Armitage, Ontario Hydro

CCOHS/CCHST

INTRODUCTION TO IONIZING RADIATION

Lillian Vine

To introduce ionizing radiation is Bhawani Pathak. Bhawani is a Project Scientist in the Physical Hazards Group at the Canadian Centre for Occupational Health and Safety. He holds a PhD in Nuclear Physics and a graduate diploma in epidemiology and biostatistics. Before joining CCOHS in 1984, Bhawani taught at the School of Occupational Health at McGill University. Currently, he is on the faculty of the school as Auxiliary Professor. He has been my advisor and a tremendous help in planning this seminar.

Bhawani Pathak

Radiation is the condition whereby energy is directed outward from a central point. The energy that is directed outward is also called radiation. The source that sends out this energy is the source of radiation.

Light and heat from the sun come to us by radiation. The same is true with hot metal and hot glass--heat comes to us by radiation. But most of us think of radiation as something that is emitted by a radioactive source and an x-ray machine. Such radiation is known as ionizing because it produces electrically charged matter when it passes through an object or the human body.

Radiation punches out one electron from the atom and thus produces a positively charged atom (ion) and a negatively charged electron. In this way ionizing radiation produces a trail of positive and negative charges as it passes through matter which is why it is called ionizing radiation.

Ionizing radiation energy is carried by either electromagnetic waves or by streams of particles. Even the electromagnetic wave that carries ionizing radiation is emitted as very short flashes which can be treated as particles, called photons.

The energy contained in each unit of electromagnetic ionizing radiation depends on the frequency of the electromagnetic wave. Low frequency electromagnetic radiation is non-ionizing. High frequency electromagnetic radiation is ionizing radiation.

Examples of electromagnetic ionizing radiation are x-rays and gamma rays. Both are very highly penetrating. If you stand near a source, they can enter the body. We have all experienced x-rays. The gamma rays coming out of radioactive substances are penetrating, too. They pass through the body and generally they have much higher energy than the x-rays used in hospitals. Radioactive substances may also emit x-rays.

Radiation energy is carried by particles as well. Such particles are emitted by radioactive substances, and by nuclear reactors and particle accelerators such as those used in medical research. There are many kinds of particles but from the occupational point of view, we are concerned with only a few.

Alpha particles are relatively heavy (radiation scale). These are atoms of helium gas with a positive electric charge. They cannot penetrate anything. Even a sheet of paper is enough to stop alpha particles.

Beta particles are electrons with a positive or negative electric charge. They do penetrate, but not very deeply. Mostly beta particles affect the eyes and the skin.

Neutrons, another kind of particle, do not carry any charge. They weigh one-fourth of an alpha particle. Because they have no charge, the only method by which they interact is by knocking around with the atoms of an object. They can penetrate quite deeply inside the body. Neutrons differ from other kinds of particles in the sense that they produce radioactive material when they are absorbed. Generally, the amount of radioactivity produced in this way is not high enough to cause concern.

We are all exposed to some amount of radiation, no matter what we do or where we do it. Background radiation comes from space and penetrates through our roofs and walls. Some radiation comes from the ground because the ground always contains some radioactive material. Even our body has radioactive material and it irradiates us to some extent.

In medicine, radiation is used for diagnosis and therapy--x-ray machines, radioisotopes, and particle accelerators are the main sources of radiation.

The nuclear fuel cycle is one of the very important contributors to radiation exposure. Uranium mining, fuel manufacturing and nuclear reactors pose the risk of occupational exposure.

In industry, radiation is used in radiography to check defects in manufactured material. Radioactive materials have been used in luminizing for decades. For example, radium was used for making luminous dials for watches. Radium is an alpha particle emitter. There has recently been a trend away from the use of radium. Tritium and promethium are increasingly being used in luminizing. We have emergency signs which do not need electricity. Light is produced when beta particles from tritium strike the phosphor mixed in a paint. But, if broken they may release radioactive tritium gas.

Even if you fly in an airplane, as you go higher in the atmosphere, there is more radiation present and a higher risk of being exposed.

Uranium mines are not the only ones that produce radon gas, other mines do, too. As you will hear, even our houses can be sources of radon.

How do we get exposed? We can be exposed in two ways. External, that is, working or standing near a source, near a radioactive substance or close to an x-ray machine. The radiation comes from outside and hits the body. In this case, we are only worried about radiation which can penetrate the body. That is gamma or x-rays.

When we inhale air which is contaminated with radioactive material, alpha particles are the main concern. If we take an alpha emitter inside the body, the emitted alpha particles are absorbed in the body. There is no way an alpha particle will leave the body. A small thickness of the tissue around where the alpha particles are emitted absorbs it, so there is a large radiation dose. That is why it is a major concern.

Gamma and beta rays, too, irradiate from internal sources, but they are distributed over a larger volume. That is why when we talk about alpha emitters like radon daughters, we worry about how much we inhale and the resulting dose to the lungs.

Different radioactive materials have a tendency to go to different parts of the body. For example, iodine goes to the thyroid. If you inhale anything which is insoluble, it goes to your lungs, but if it is soluble, it can go to other parts of the body.

The quantity of radioactive material is measured in Becquerels (Bq). The old unit was Curie (Ci). Curie and Becquerel are measures of the amount of radioactivity. Curie is a very big unit and Becquerel is small (37,000 million Bq = 1 Curie). When you hear about a source in Bq you hear about kilobecquerel, Megabecquerel, or Gigabecquerel because it is a small measurement. One Becquerel equals one disintegration per second.

Many instruments which measure x-rays and gamma rays give the exposure in roentgen (R). Roentgen is a measure of the radiation in the air around you; it is ionization in the air. One Roentgen per hour exposure causes about 1 rad per hour dose.

The risk of harm depends on the amount of energy radiation deposits in the body. This is called absorbed dose and measured in Gray (Gy). The term "karma" is sometimes used to describe dose. Karma is the amount of kinetic energy per unit mass of matter and is measured in Gray (Gy).

Radiation energy is not the only factor related to health risk. The type of radiation also matters when you talk about harm. One Gray of alpha dose causes far more harm, about 20 times more, than one Gray of gamma dose. That must be taken into account.

"Dose equivalent" or "dose" takes into consideration both the absorbed dose and the type of radiation. Dose is expressed in Sievert (Sv). Dose in Sievert is calculated by multiplying absorbed dose with quality factor which depends on the type of radiation. One sievert is a big dose. That is why in the scientific literature dose is generally expressed in millisievert which is one thousandth of a sievert. All scientific papers do not use sievert yet. You also hear about "rem"; 1 sievert equals 100 rem. If someone says there is exposure of 1 rem, the exposure is .01 sievert (10 mSv).

Concentrations of radon daughters in the air are measured in working levels (WL). Working level is the concentration of alpha particle energy in the air. Exposure is given as working level months (WLM). One working level month is 170 hours, or one month of work in a workplace where radon daughter concentration is 1WL.

How much radiation exposure can we take? Atomic Energy Control Board (AECB) Regulations tell us that a radiation worker is allowed up to 50 mSv per year. That is, 5 rem per year. The general public is allowed 5 mSv per year, which is 0.5 rem. Uranium mine and

mill workers are allowed to be exposed up to 4 WLM per year. Pregnant women are allowed lower dose limits, generally during the term of known pregnancy; it should not exceed 10 mSv (1 rem).

These doses are given on the basis of risk. In certain situations the whole body is not irradiated, the dose goes to only one particular organ or tissue. In that case, to calculate how much dose should be allowed, one uses a weighting factor. These are sets of weighting factors. One particular organ is allowed a higher dose than the whole body dose. The following weighting factors are used:

0.25 Ovaries and testes
0.15 Breast
0.12 Red bone marrow
0.12 Lungs
0.03 Bone surface
0.03 Thyroid
0.3 Remainder (5 organs x 0.06)
1.00 Whole body, risk 0.01/Sv

Often we hear about other kinds of doses, other recommendations which are not law. These are recommended standards. One that is most often heard and generally adopted is the recommendations of the International Commission on Radiological Protection (ICRP). The recommendations of ICRP are not the law but standards based on risk factors. Besides that, there are also many international bodies which come up with recommendations, guidelines, safety procedures, safety guides, and such.

What does radiation do to us and how do we know about it? From early days, people knew that radiation could affect the body. What we know today comes from the experiences and exposures of people at a very high dose rate. For example, one of the major sources of data is cancers in atom bomb survivors; cancers in people who suffered from fall-out from nuclear bomb tests; leukemia and skin cancers in radiologists when occupational doses from x-rays were much higher than they are today. Radium was used to make watch dials luminous by mixing radium with luminous paint. People who painted these dials later suffered from cancers of the bone. The medical profession used radioactive sources for many procedures; people who received radiation in medical procedures later suffered a higher incidence of cancers than others.

Radiation can affect us in two ways. Some effects occur right away, within days or weeks after exposure. Such effects are known as acute effects, acute radiation syndrome, radiation sickness. They are likely to occur if a very high dose of radiation is received within a short time. Such doses are not possible in occupational settings unless there is an accident. We have no details of acute radiation syndrome from an occupational point of view and there appears to be little risk of such a thing.

Other effects are late effects. These effects occur several years after exposure at low doses. Leukemia occurs 2 to 5 years later, bone cancer 8 to 9 years, lung cancer several years later, depending on the dose and other variables. They occur randomly. In a large exposed population, only a few people are going to get cancer. We cannot tell beforehand who these people will be. That is why the matter is treated statistically and a numerical value of risk (probability) is derived on the basis of incidence rate.

Radiation is not the only cause of cancer. There are unknown causes, there are chemicals. The sum and substance is that if somebody gets cancer, one cannot say whether it was caused by radiation or not. The only way to tell is if you know the exposure history.

ICRP has summarized risk values and concluded that if in a group of 100 persons each is exposed to 1 Sv dose, there will be risk of 1 excess cancer over the population rate.

Radiation risk does not stop at the exposed persons. Radiation, besides affecting people who are exposed, can affect the future generations of the exposed persons. Because radiation can alter the genetic material in the body, there is a possibility that the offspring may have genetic abnormalities which might translate into mental retardation, bodily malformation, childhood cancers.

The genetic risk for radiation protection is estimated to be 4 in 1,000 for each Sv dose (ICRP-26).

Exposure of the fetus to radiation is potentially more harmful than exposure of adults. The data suggest that exposure at the stage of pregnancy when organs are developing is still more harmful and can lead to malformations.

One thing about the genetic effects--there are no human data, all we know comes from animal experiments. Radiation dose during pregnancy can cause malformations or make children more prone or at higher risk of childhood cancers.

The lens of the eye is affected by radiation; certain types of radiation like beta rays are likely to give a higher dose to the eye. There is a threshold dose below which cataracts are not known to develop. Radiation can cause changes in the skin at very high doses.

Some people believe that radiation can cause premature aging or shorten life. There is no concrete evidence that it does so except for the risk of death from cancer. Radiation does produce sterility at very high doses; but there is no evidence that occupational doses cause sterility.

We cannot ignore radon daughters. When inhaled, radon daughters give an alpha dose that causes lung cancer. Dose from radon daughters is basically confined to the lungs which are the most affected organ whether the radon daughters are found in the mine or in the home. Data that have been reviewed estimate 350 cancer deaths per million persons. These are excess cancers for radon daughters per working level month of exposure. This risk is for people with unknown smoking habits; smoking greatly increases the risk of lung cancer from radon.

There is a new report, BEIR V, Biological Effects of Ionizing Radiation Committee, which has come up with higher risk numbers from low level ionizing radiation.

The United Nations Scientific Committee of Effects of Atomic Radiation (UNSCEAR) which reviews the literature shows risk values not to have changed much for high dose rates where people receive higher risks over a short time.

Radiation is a fact of life. No matter where we go, we are exposed to some radiation but we can control it. We can avoid radiation to a large extent by time/distance/shielding, which means less exposure time, stay away from it, and if you can, interpose some material in between. Internal exposure should be avoided the same way exposure to chemicals is avoided.

Lillian Vine

I am pleased that Maureen Shaw, Chairman of the Council of Governors of the Canadian Centre for Occupational Health and Safety, has joined us. I would like to call on her.

Maureen Shaw

I would like to welcome you to CCOHS' seminar and, if this is your first, I hope you will return for a second, third and fourth. I am looking forward to meeting with you and sharing some thoughts and ideas with you. I hope you have a very good day. Welcome on behalf of the Council of Governors.

Lillian Vine

Our President and Chief Executive Officer, J Arthur St-Aubin, has been at the Centre for less than a month. I am delighted that he is with us this afternoon.

J Arthur St-Aubin

Thank you. I am looking forward to hearing the speakers this afternoon. One of the reasons for my keen interest is not so much as a practitioner or a scientist, but as a guinea pig. I am one of the few people still around who has undergone a nuclear weapons explosion. In 1957 when there was nuclear testing in Nevada, I was one of the people at the bottom of a six-foot trench 800 yards from ground zero for a 50 kt shot. In full battle gear, we were told to sit down with our backs to the explosion. We were wearing very heavily smoked rim goggles. We were told to sit with our knees bent and our head on our knees with our eyes closed. When the explosion went off I saw a perfect X-ray of the bone structure in both forearms. That gives you an idea of the intensity of light they generate. To this day the University of Ottawa calls me every couple of years to see how I am. And ever since then I have been interested in this field; I look forward to these deliberations and I am delighted to be with you.

RADON - A SILENT KILLER?

Lillian Vine

Denis Brown holds a BSc degree in Physics from the University of London, a MSc degree in Radiation Protection and a PhD in Radiation Physics, both from the University of Surrey. He is a corporate member of the Institution of Electronic and Radio Engineers (UK) and of the Institute of Physics (UK). He is also a Certified Health Physicist.

Denis has been a lecturer in Physics and Radiation Safety at many levels. He was Radiation Protection Adviser and Honorary Principal Physicist to the National Health Service, University of Aberdeen. From 1974 to 1978 he was Consulting Health Physicist to various industrial companies including three years under contract to the Safety Division, Shell UK Exploration and Production Company as Radiation Safety Officer. From 1978 to 1980 he was Senior Physicist at the Allan Blair Memorial Clinic in Regina (Saskatchewan Cancer Foundation). There he was responsible for radiation protection arrangements in the medical service and was particularly involved in the design and implementation of quality control programs covering all aspects of diagnostic radiology and nuclear medicine within the Clinic. Since 1980 he has been the Chief Radiation Health Physicist in the Saskatchewan Department of Labour where his duties include responsibility for establishing and coordinating province-wide programs covering all health-related aspects of the use of ionizing and non-ionizing radiations.

Denis Brown

I was a little amused to find that, while the other speakers were speaking on conventional unemotional titles, I had been given the very dramatic title shown in the agenda. It is worth noting that this is not the first time the word "killer" has been applied to radon. An article in the Canadian magazine Living Safety in 1988 was entitled "Radon: Killer Under Control" and the Globe and Mail newspaper has referred to radon as a "killer gas." Why this difference in treatment for radon? It is probably because we can select our occupation, and hence the occupational hazards to which we are subject. But radon is something that none of us can get away from no matter what we do, unless we spend all our time at sea where the levels are very low. The general recognition that radon inhalation constitutes by far the largest part of the background radon exposure to which we are all subject has led to its receiving a lot of attention during the past few years; and has resulted in a few individuals who are almost paranoid in their fear of any sort of radiation exposure panicking at the thought of any radon getting into their homes. On the other hand, it has not led to any great concern on the part of the typical member of the public who tends to recognize that radon has always been present in buildings and always will be. It would probably be more productive to worry about some of the more recent man-made toxic agents that we stand some chance of controlling effectively.

My task today is to steer a path between two extremes. In some homes (fortunately it appears from present data these are only a small minority) radon levels are high enough to cause significant concern and it is certainly a sensible investment for the homeowner to spend some hard-earned money taking steps to reduce the level. Nevertheless if s/he is a smoker the hazard associated with radon in the home will, except in a very few extreme instances, be far outweighed by the hazards associated with the cigarettes. Ultimately then, should we regard radon as a "Silent Killer"? An analogy is that in tiger-country, one would certainly think of man-eating tigers as killers, but still recognize that even there one would have to be pretty unlucky to fall foul of one. We all have many more urgent worries competing for our attention.

We are, of course, all exposed continuously to low levels of background radiation which do not usually cause us undue concern as they have been present throughout the history of the world. If we look at a pie chart showing how the typical radiation dose received by Jane or John Citizen is divided, we find that radon inhalation represents the largest slice.

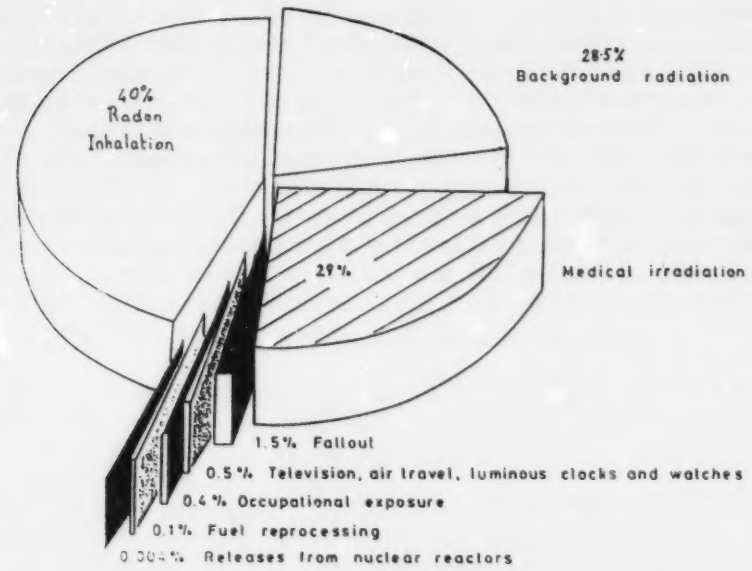


Figure 13 - Approximate Contributions to the Population Dose

In its 1988 Report the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) estimates that the average natural radiation dose received per person is 2.4 mSv of which 1 mSv arises from gamma radiation and 1.4 mSv from the inhalation of radon. By contrast UNSCEAR estimates that medical uses of radiation give an average radiation dose per person of about 1 mSv in countries where advanced radiological facilities are generally available, and (ignoring Chernobyl-type accidents) nuclear power generation contributes an average dose of only 0.01% natural background. Even if we generated all our electricity through nuclear power this would contribute only 0.1% of our normal background. Our concern about radon arises primarily because its contribution to our dose is so variable. The average dose listed above is not very high; most individuals receive a dose far below the average while an unknown few receive doses many times this average.

To assess how concerned we should be about radon in our homes, we need to look not only at what is known of the risks of inhaling radon but also at what information there is about radon levels in typical Canadian homes. We cannot do this without first taking a further step back and considering what radon is and where it comes from. This step back can take us as far as the origin of our galaxy when the original primordial "big bang" created atoms from a plasma of fundamental particles. We believe that this original act of creation produced both radioactive and stable isotopes of all the elements we know today. A radioactive atom is one which will decay spontaneously into a different type of atom. Over the billions of years our galaxy has existed most of these radioactive atoms have decayed into stable products so that, if we need them, the radioactive forms of most atoms now have to be produced artificially. However a very few of these original radioactive elements change so slowly that they are still present in significant quantities on earth today. One very important example of these original radioactive elements is uranium. The element uranium was first discovered on earth by the German chemist Martin Klaproth in 1789. It is not particularly scarce--a typical suburban garden plot of 10m x 40m will contain about 2Kg of uranium in the top meter of soil, and the concentration usually increases as one goes deeper.

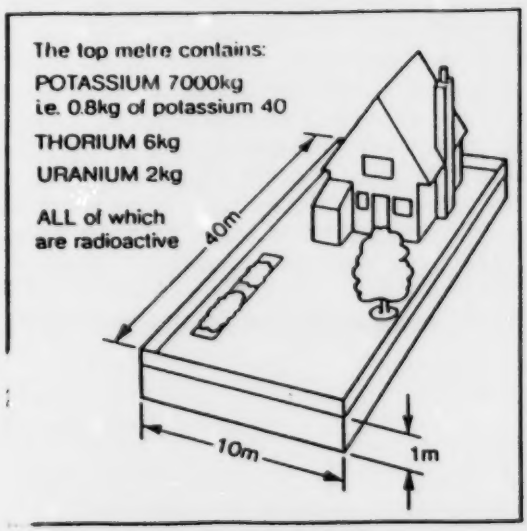


Figure 14

Klaproth did not appreciate that uranium is a radioactive atom which is unstable. In fact, radioactivity was only discovered in 1896 by Henri Becquerel. This set the stage for a period of intensive research, in which Marie and Pierre Curie took a leading part, which showed that each uranium atom undergoes a series of eighteen radioactive changes before it eventually becomes a stable atom of ordinary lead. The sixth radioactive change of a uranium atom produces an atom of radium, a radioactive element first isolated by Mme Curie in 1902. The next decay product is the element radon which is a noble gas (one that will not normally form any chemical compounds and which therefore always remains in a gaseous form). Because radon is a gas it is unique among the uranium decay products. The radium from which it is formed, like uranium itself, forms an integral chemical part of most rocks and soils; but the radon will not be held by a chemical bond and can diffuse to the surface of the rock or soil particle from where it can escape into the surrounding air. The released radon will be proportional to the amount of radium present and this in turn is often (but not always) directly proportional to the amount of uranium. Since uranium is a common constituent of most rocks and soils the air in the spaces between the separate grains of soil will normally contain a significant concentration of radon gas which may be quite high in certain places.

The soil gas gradually diffuses out from among the particles of soil and mixes with the atmosphere which initially includes practically no radon. Because of fairly rapid mixing, the air in the atmosphere does not normally build up a high radon concentration like the soil gas, and the amount of radon present will normally decrease rapidly with altitude. The atmospheric radon level will be greatest over rocks or soils with a high radium content (for example, uranium mine tailings piles) and conversely will be very low over the sea. However, even under the most unfavourable conditions, it is seldom high enough to be of any health concern. The problem is that radon rich soil gas is frequently sucked into the basement of buildings to such an extent that radon levels in the building may be ten to a hundred times higher than in the air outside. This reduction of air pressure in the basement of a building results mainly from the air flow pattern around the building and is often augmented in winter by the action of a hot air heating system. This can readily cause occupants of the building to breathe air containing a potentially hazardous concentration of radon.

Radon is colourless and odourless. It produces no immediate harmful effects or other symptoms by which it could be recognized. Unfortunately it is a carcinogen which can cause lung cancer many years after the exposure took place. Cancer is a disease associated with the uncontrolled proliferation of a group of cells in the body which first leads to the development of a tumour (or in the case of white blood cells, leukemia) and eventually results in the destruction of vital body tissues. It is caused by the breakdown of the built-in mechanism all cells normally have to prevent such uncontrolled proliferation. This breakdown may be initiated in some way which we do not yet fully understand by ionizing radiation or by hazardous chemicals such as those in cigarette smoke; but it does not develop for many years, usually appearing after three to ten years in the case of leukemia but after as long as fifty years for some solid tumours.

Our appreciation of this long term risk is largely based on the experiences of undergound uranium miners who typically worked in atmospheres containing high concentrations of radon, and who subsequently experienced an usually high incidence of lung cancer. Knowledge of this problem goes back a very long time to even before uranium itself had

been discovered. A silver mine in the town of Joachimstahl in the Erzegeberge mountains in central Europe was for many years in the early sixteenth century the home of an unusually far-sighted Italian physician, Georgius Agricola, who in his book, De Re Metallica, clearly documented the symptoms of the "mountain sickness" to which these miners were subject. He refers to it as a terrible consumption which eats away the lungs so severely that some of the women in the town had been widowed seven times. This silver mine eventually became the world's first uranium mine and was the source of the supply of pitch blende from which Mme Curie first isolated radium. It is interesting to note that this mine only finally closed less than 20 years ago, and that the town, like many similar ones, is now a spa to which the prosperous can return for radium baths and radon inhalation treatments. It is also interesting that in North America we have a close link with this town. The silver which it produced was used for coins originally known as Joachimstahlers; this was later abbreviated to Thalers, a word which was eventually corrupted to dollars.

Radon itself is not the primary carcinogen which leads to such lung cancers. Actually the most important carcinogens are the immediate radioactive decay products of the radon gas known as the radon daughters.

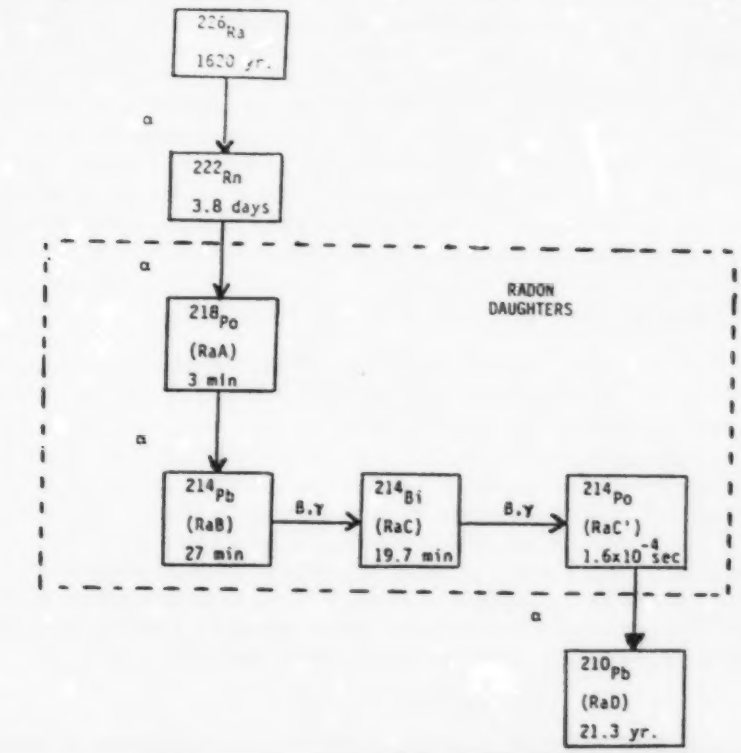


Figure 15 - Decay Chain for ^{222}Rn and Its Progeny

If the radon decays in air these are formed as isolated but chemically active atoms that are breathed in along with the radon gas and, because of their chemical reactivity, are likely to be deposited along the walls of the bronchial tracts leading to fairly intense irradiation of the very sensitive cells lining these walls.

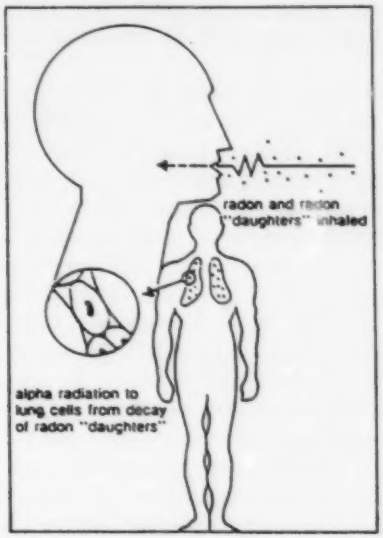


Figure 16 - Health Risk

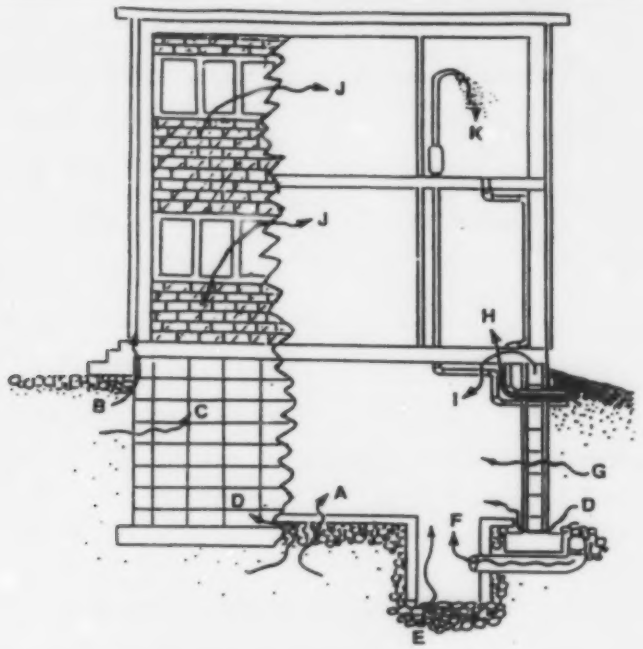
This problem is aggravated by the fact that two of these radon daughters are alpha emitters. When an atom undergoes radioactive decay it typically emits highly penetrating gamma rays which form the most important part of the ordinary background radiation to which we are all exposed. In addition it will eject either an alpha or a beta particle. Beta particles have a negative electric charge and weigh very little. They move with speeds close to that of light and have considerable penetrating power. Most radioactive materials emit beta particles but some, including these radon daughters, emit alpha particles which have a positive electric charge and are almost 8,000 times heavier than beta particles so they have very limited penetrating power. Consequently, most of their energy is released within a very small volume comparable to the size of a single cell. This makes them much more likely to produce serious biological damage. In health physics terms, alpha particles are said to have a "relative biological effectiveness" twenty times greater than gamma rays.

When occupational health requirements began to be introduced into the mines it became necessary to measure the actual exposures of workers to the radon daughters. The weighted concentration of all the daughters present in the air was measured in "working levels" and the total radiation dose a person received was given in "working-level-months" (WLM) where a working level month was defined as the dose a person

would receive during a month in which 170 hours were spent in an atmosphere containing one working level of radon daughters. It is not surprising that these definitions were based on the concept of a "working level" as an acceptable level for continuous occupational exposure, and imply a permissible annual dose of 12 WLM. In practice, however, the permissible dose has been reduced to 4 WLM per year which means that the acceptable radon daughter level for continuous occupational exposure is now 0.33 working levels. In Saskatchewan this is further reduced to allow for whatever gamma radiation dose is also received by the miner. Even so, in 1988, 85% of the Saskatchewan uranium miners received radiation doses below one-tenth of the provincial maximum.

Studies of the actual exposure of miners to radon daughters and of the increased incidence of lung cancer which they experienced later were first reported from the Colorado plateau in the USA in 1967. Similar studies from Czechoslovakia were completed soon after, and since then data have become available from many other countries including Canada, Sweden, the UK, France and South Africa. For a long time it was thought that these studies were only relevant to the health of uranium miners. It was appreciated that elevated radon levels did occur in some homes but it was not recognized that these could be high enough to constitute a significant risk. This changed dramatically when a nuclear power station worker in Pennsylvania, Stanley Watrous, blew the station contamination alarm every morning when he reported for work. An investigation showed that his clothing and skin were contaminated with radon decay products absorbed in his home, and that the radon level in his basement was about fifty times greater than the peak levels in most uranium mines. Since all homes inevitably contain enhanced radon levels this has led to ongoing concern to establish acceptable levels and to define the risk attributable to radon at different concentrations, a process that has not yet ended. It has also inevitably led to concern that maximum workplace exposures to radon should be regulated even when these exposures arise entirely from natural causes.

In underground mines today very powerful forced ventilation systems are used to remove radon daughters and to produce a working environment that is safe for the miners to breathe. Under these circumstances measurements of the radon level in the air cannot be used to indicate the potential hazard, which is why radon daughter measurements are made and recorded in working levels. Homes are not generally subject to high forced ventilation rates and measurements of radon gas which are much easier and less expensive to make are perfectly adequate for assessing the hazard to the occupants. In addition, the radon levels frequently fluctuate wildly making it desirable to obtain an average value over a substantial period of time. This is more easily done for radon than for radon daughters.



- RADON ENTRY INTO BUILDINGS -

A. Cracks in basement slab.
B. Space between outer wall and drywall panels when resting on hollow block foundation.
C. Mortar joints between blocks.
D. Joint between walls and basement slab.
E. Sump pump.
F. Weeping tile system discharging to open sump.
G. Cracks in basement walls.
H. Around pipe entry channels in basement floor or walls.
I. From the open top of hollow block structures.
J. Radon released from building materials containing radium, (some bricks, drywall boards, concrete etc.).
K. Dissolved radon released from deep aquifer water supplies.

Figure 17 - Radon Entry Into Buildings

Figure 17 shows typical radon entry routes into normal buildings. The amount of radon present can easily be measured using a charcoal cannister or track etch radon monitor. Even after the presence of significant levels of radon has been confirmed by measurements it is often very difficult to be sure how the radon entered the building. Unfortunately each building is different in three important respects--its construction and integrity, the adjacent air flow patterns and the exact nature of the subsoil. Predicting radon levels in individual buildings from other measurements made in the same area is therefore usually a futile occupation, although sometimes it is possible to predict that high radon levels are very unlikely in certain areas.

COUNTRY	UPPER GUIDELINES (Bq/m^3)	LOWER GUIDELINES (Bq/m^3)
Canada	800	—
ICRP[1]	400	200
WHO[2]	200	—
U.S.A. (EPA)	800/150	150
U.K.	400	100
Germany	400	—
Sweden	800	200
Finland	800	200

1 - ICRP - Internal Commission on Radiological Protection

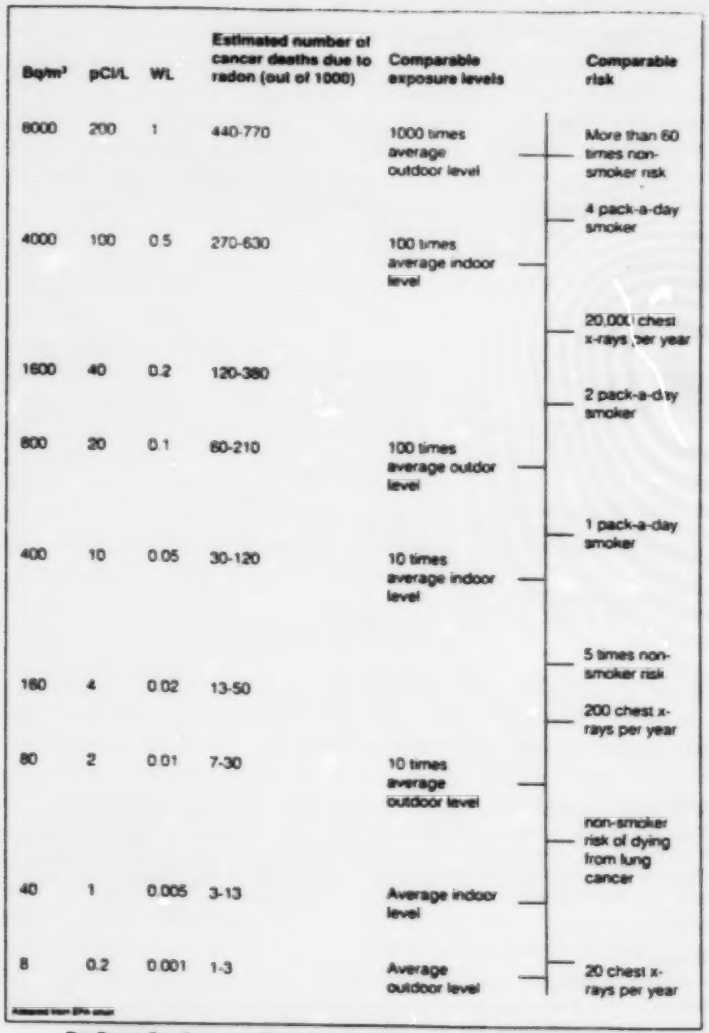
2 - WHO - World Health Organization

1 - Bq/m^3 = 0.027 pCi/l

Figure 18 - Adopted or Proposed Standards for Radon in Indoor Air

Figure 18 shows the levels of radon at which various authorities recommend taking corrective action. In both the USA and Canada, it is generally recommended that urgent corrective actions should be taken if the level in any occupied part of a building exceeds 800 Bq/m^3. (The USA still uses the old system of units where this is equivalent to 20 pCi/l.) No corrective action is warranted if the level is below 150 Bq/m^3 (4 pCi/l). However the actual recommendations are phrased rather differently, with the emphasis on the lower limit in the USA and on the upper limit in Canada. This sometimes results in magazine and newspaper articles incorrectly suggesting that there are significant differences in the actual recommendations.

Where buildings have high levels of radon in occupied areas it may be possible to correct these by improving ventilation. Attempts may be made to seal the basement or crawl space against the entry of radon from the soil. But, in general, the best procedure is to reduce the pressure of the soil gas by inserting perforated pipes vented to the atmosphere so that radon is no longer sucked into the building from the surrounding soil. Such remedial work typically costs between a few hundred and a few thousand dollars, although in extreme cases it may be even more expensive.


Bq/m³
pCi/L
WL
Estimated number of cancer deaths due to radon (out of 1000)
Comparable exposure levels
Comparable risk
8000 200 1 440-770
1000 times average outdoor level
More than 60 times non-smoker risk
4 pack-a-day smoker
4000 100 0.5 270-630
100 times average indoor level
20,000 chest x-rays per year
1600 40 0.2 120-380
2 pack-a-day smoker
800 20 0.1 60-210
100 times average outdor level
1 pack-a-day smoker
400 10 0.05 30-120
10 times average indoor level
5 times non-smoker risk
160 4 0.02 13-50
200 chest x-rays per year
80 2 0.01 7-30
10 times average outdoor level
non-smoker risk of dying from lung cancer
40 1 0.005 3-13
Average indoor level
8 0.2 0.001 1-3
Average outdoor level
20 chest x-rays per year

The Radon Risk Evaluation Chart compares the estimated risks associated with exposure to radon with the more familiar contributors to lung cancer

Figure 19 - Risk Estimates for Radon Inhalation

Figure 19 shows the lifetime lung cancer risk associated with living in buildings with various average radon levels. These are ceiling values based on 24 hour occupancy a day throughout a lifetime, a rather improbable circumstance. It has been copied from a US EPA publication, and the risks it shows are somewhat higher than most Canadian scientists believe to be justified. This is because it is based directly on the studies on uranium

miners, and largely ignores similar studies of populations living in areas where there are higher than average natural levels of radon which tend to lead to somewhat lower risk estimates. Many scientists believe that there are other factors present in underground mines which increase the risk to workers, and that more attention should therefore be paid to the data from high radon areas when evaluating the risk from radon in buildings. Several such studies are currently in progress in several countries, including one Canadian study being carried out in Manitoba; when these are completed it should be possible to estimate radon risks with significantly better accuracy. To compare different studies it may be necessary to be able to convert between readings made in different units as these still show little uniformity. Approximate conversion factors which can be used for this purpose are shown in Figure 20.

Radon gas levels
1 Bq.m-3 = 2.7 x 10-2 pCi.l-1
1 pCi.l-1 = 37 Bq.m-3

Radon gas levels to radon daughter concentrations
1 Bq.m-3 = 0.5 Bq.m-3 EER = 1.35 x 10-4 WL (approx)
1 pCi.l-1 = 0.5 pCi.l-1 EER = 5 x 10-3 WL (approx)

Radon daughter concentrations
1 WL = 3.7 x 10-3 Bq.m-3 EER = 10-2 pCi.l-1 EER
1 Bq.m-3 EER = 2.7 x 10-2 pCi.l-1 EER = 2.7 x 10-4 WL

Radon and radon daughter exposures
1 Bq.y.m-3 (8.76 x 103 Bq.h.m-3) = 2.7 x 10-2 pCi.y.l-1
= (approx) 7 x 10-3 WLM

1 pCi.y.l-1 (8.76 x 103 pCi.h.l-1) = 37 Bq.y.m-3
= (approx) 0.25 WLM

1 WLM = 12.57 x 105 Bq.h.m-3 1.44 x 102 Bq.y.m-3

Note that the WLM (working level month) is a unit of occupational exposure based on a working month of 170 hours. There are therefore (confusingly) 170 working level hours of exposure in one WLM, but 51.53 WLM of exposure in a working level year. Confusion is minimised if the WLM is regarded as the name of a unit and is not referred to as a working level month.

Radon risks
If it is desired to compare the lifetime cancer risk from exposure to radon in buildings with that from exposure to normal background radiation, the conversion recommended by the International Commission on Radiological Protection is that continuous exposure to 1 Bq.y.m-3 EER results in a risk equivalent to that from 8.76 x 10-2 mSv of whole body radiation. In practice this means that spending 24 hours a day in a buildings with a radon in air level of 2 Bq.m-3 (1 Bq.m-3 EER) produces a risk about 10% of that arising from other components of the average background radiation.

Figure 20 - Unit Conversion Table

I began this talk by saying that the only hazard associated with high levels of radon is an elevated risk of developing lung cancer. This has almost always been assumed to be true. I have mentioned that the radon daughters which are responsible for most of the risk are primarily alpha particle emitters and that alpha particles have very limited powers of penetration. In fact, when they strike the human skin their energy is totally absorbed in the layers of dead and dying cells on the surface and they cannot penetrate to the radiation-sensitive base level below. The power of radon and its daughters to do biological damage from outside the body is therefore much less than that of penetrating gamma radiation. Only when the radon has been inhaled into the respiratory system, or ingested into the digestive tract, can the alpha particles penetrate through the surface protective layer and damage the sensitive tissues beneath. Radon can enter the digestive tract, for example, through drinking water in which radon has been dissolved. Studies have been carried out to determine whether this can lead to stomach cancer; the results were inconclusive but it was clear that any such outcome was highly improbable. Consequently radon risk studies have always concentrated exclusively on the lung cancer threat. An interesting recent development in the radon story was a paper published in the UK medical journal The Lancet on April 28, 1990. This proposes the novel theory that radon dissolved in fat cells in red bone marrow may significantly irradiate the stem cells which generate white blood corpuscles, and may thereby initiate the development of leukemia. The authors of this paper have studied the incidence of myeloid leukemia in fifteen countries and claim to have demonstrated that this shows a significant correlation with areas where there is a high natural background radon level. The authors estimate that between 13% and 25% of cases of myeloid leukemia may be attributable to the inhalation of natural radon. This is a very controversial theory about which we shall no doubt hear a great deal more in the months to come.

What can we do about radon? At a national level, we are trying to do two things. The first is to modify our building codes to minimize the extent of the problem in future new homes. It is possible to build a home so that it is very nearly radon proof but this is unnecessarily expensive in the vast majority of cases where there is no serious radon problem. The current proposal is therefore to amend the building code to require all basements to incorporate a plastic radon barrier and to make provision for the retrofitting or a sub-soil ventilation system at a later date should this prove necessary. These simple requirements would add very little to the cost of a new home but would not greatly reduce the need for the eventual owner to have a radon survey carried out. The second government initiative, which is being taken at both provincial and federal levels, is to make information about the problem available to all Canadians.

NUCLEAR INDUSTRY - HAZARDS AND BENEFITS

Lillian Vine

Gerry Armitage, our next speaker, was born in a small coal mining village in Yorkshire, England. After attending the local schools, he studied chemistry at the University of Bradford from which he graduated with a BSc degree.

In 1968, he emigrated to Canada and began working for Ontario Hydro at Douglas Point Nuclear Generating Station as an Assistant Health Physicist. In 1970, he began working at the Bruce Heavy Water Plant and after developing worker safety systems became a Shift

Supervisor. In 1975, he joined Atomic Energy of Canada Limited and became Production Manager at Glace Bay Heavy Water Plant. In 1979 he returned to Ontario Hydro and the radiation safety field. After spending two years as Senior Health Physicist at Bruce Nuclear Power Development, he was appointed to his present position as Manager of the Health Physics Services Department in 1982.

Gerry Armitage

The views that I present here are my own; I am not speaking on behalf of Ontario Hydro. Much of what I say is influenced by my childhood. In my father's mining family are three uncles I never met because they had been killed before I was born and two aunts I never met because they died in childhood. On the other hand, in my mother's family, who were rich mill owners, I knew all my uncles and aunts.

I want to give you some idea of the risks of the nuclear industry. People's perception of risk is subjective. I will try not to be judgmental. My expectation is that those who are interested will follow up by reading some of the available material and draw their own conclusions. After looking at the risks, I will try to determine if there are any benefits.

To try to evaluate risks, ideally one should take a systems approach and evaluate the whole spectrum of risks over the lifecycle of the system. Unfortunately this presents some difficulty because through the lifecycle of any system there are differing types of risks. There are acute events, such as fatal accidents and non-fatal accidents; there is damage from chronic exposures to chemical and physical agents where the impact may not become obvious for many years after exposure; there is the low frequency, high consequence event where a catastrophic accident happens. One must ask "Does a one in ten thousand annual chance of a 10,000 death event equal one death a year on a chronic basis?" Numerically it does, but in the mind it may not.

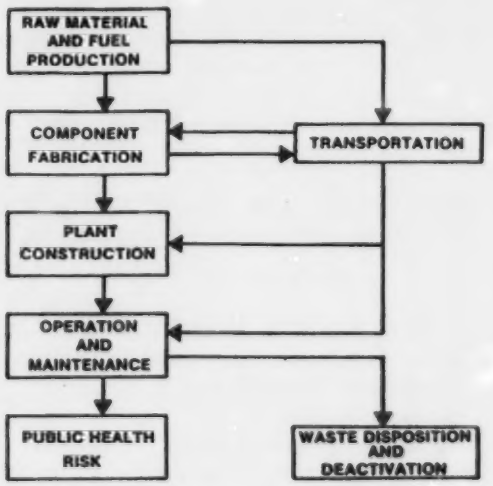


Figure 21 - Sources of Risk in Energy Production

A number of system risk evaluations have been performed looking at nuclear power. One of the better ones was done by a Canadian, Herbert Inhaber, and this model (Figure 21) was taken from his paper; he looked at everything in terms of producing nuclear electricity--raw materials, fuel production, component fabrication, construction, operation and maintenance, and waste disposition. He looked at public health risks as well as occupational risks. Many studies were also done in the USA, in Sweden and in the UK.

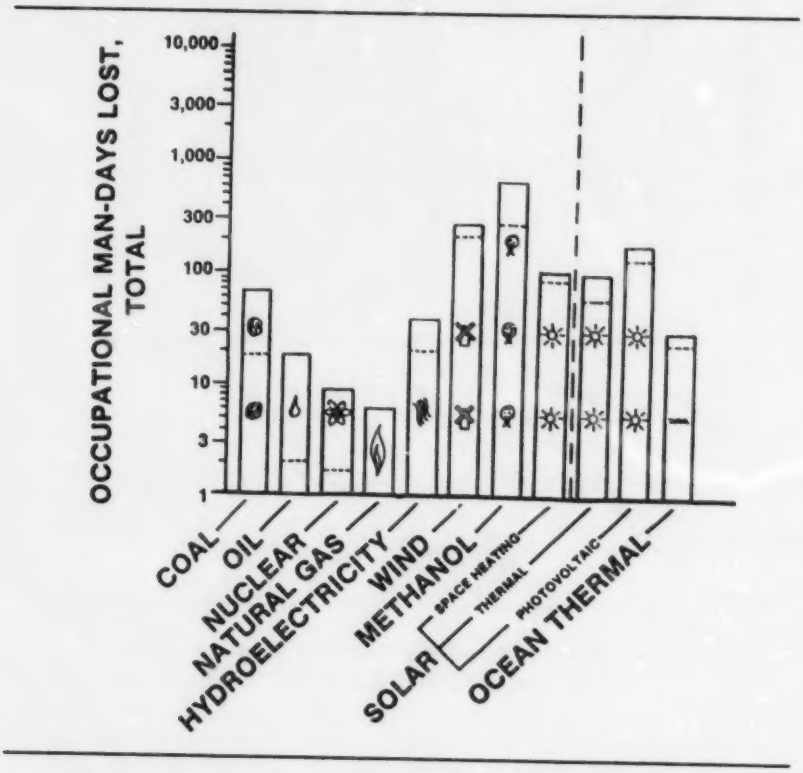


Figure 22 - Occupational Man-Days Lost per Megawatt-Year Net Output Over Lifetime of System

Figure 22 shows the typical results obtained from these studies. They tried to quantify the risk in terms of person-days lost per unit of electric output. This is a comparison between various ways of producing electricity. For this purpose they assumed that each occupational death was equivalent to 6,000 man-days lost (30 years of working life). The top of the bar represents the maximum and the dotted line is the lower estimate. You can see some very surprising numbers. Perhaps the most controversial are the ones on the extreme right which are considered to be benign--solar thermal, photovoltaic, ocean thermal. I will explain why the numbers are so high later.

CCOHS/CCHST

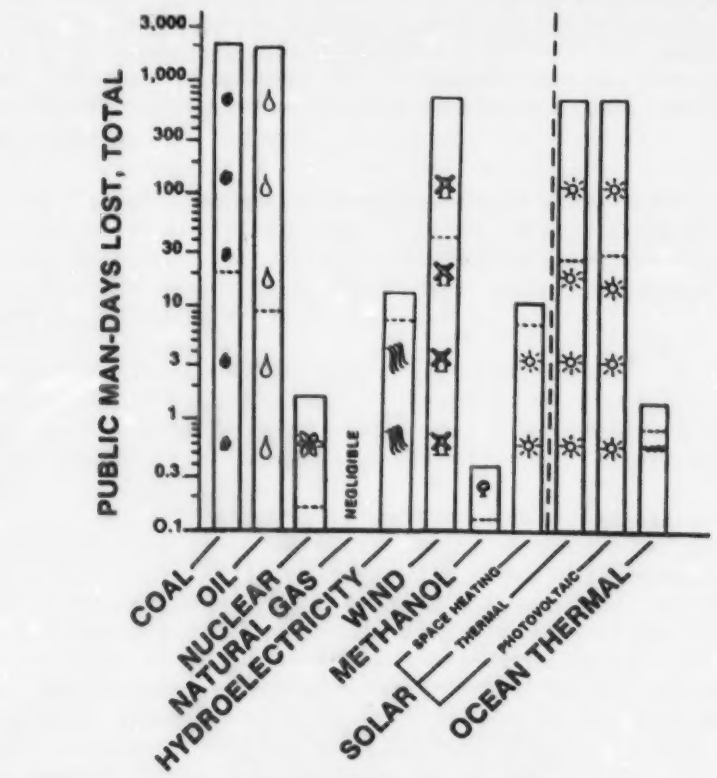


Figure 23 - Public Man-Days Lost Per Megawatt-Year
Net Output Over Lifetime of System

In addition to occupational risk, there is public risk. In the case of coal- and oil-fired generation of electricity, the risks are mostly in transportation and/or pollutants which are pumped into the atmosphere. In the case of nuclear energy, the largest component is emission during a routine operation and some component for the catastrophic accident. The range of estimates are denoted by the top of the bar and the dotted line.

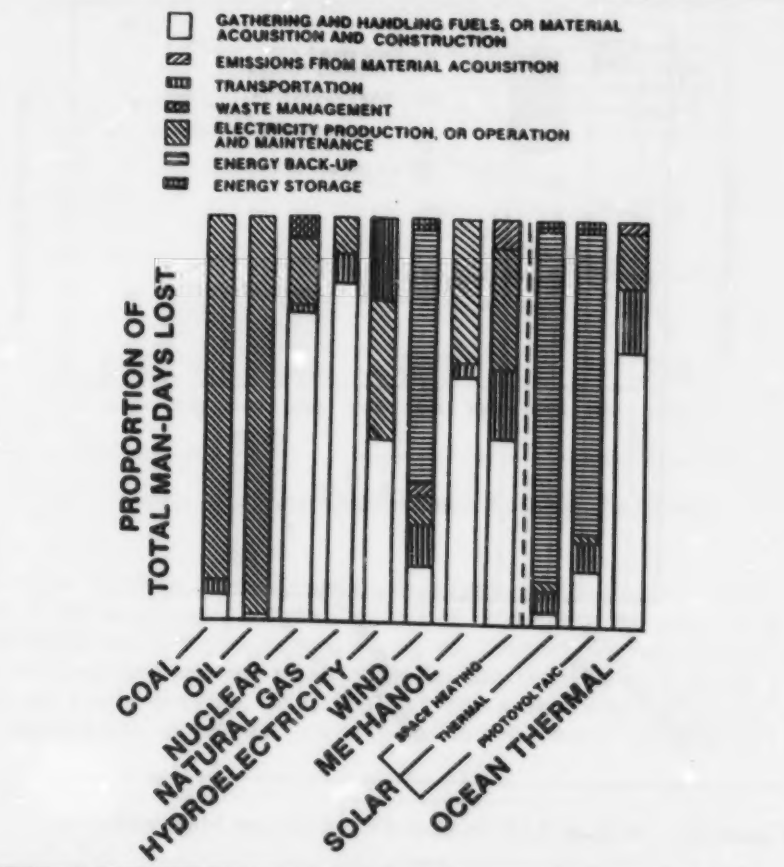


Figure 24 - Proportions of Risk by Source

Inhaber also attempted to portray the proportion of the risk by its source. In Figure 24 you will see that in the case of coal and oil it is mostly the operational phase which produces the risk. In the case of nuclear energy, it is mostly in the gathering and handling of the fuel. In the case of the solar systems and ocean thermal, the largest portion is due to what Inhaber called "energy back-up." In his logic, he said that to have an effective system you must be able to provide electricity all the time. It is not acceptable for people to press the switch and have no lights come on just because the sun does not shine, which is the implication of a photovoltaic system. You must have some kind of back-up or storage system. When it comes to back-up, what it inevitably means is coal, oil or gas thermal electricity production.

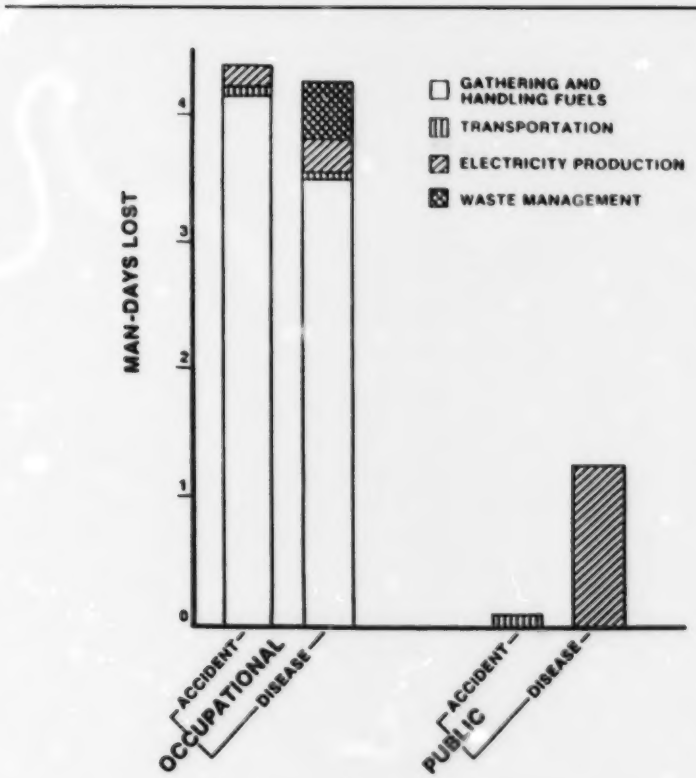


Figure 25 - Nuclear Risk in Man-Days Lost per Megawatt-Year

Figure 25 shows the two major components in nuclear risk--accidental and occupational disease and similarly for public exposure. Notice that the occupational risks are much larger than the public risk.

That is all very well. It is somewhat theoretical and is the result of reviewing lots of information, some of which is very sketchy. What I would like to talk about now is Ontario Hydro's experience.

Since 1962, when Ontario Hydro's program began, there have been no conventional occupational fatalities. Our employees have worked more than 140 million person-hours, so from that point of view one could say that it is fairly safe. Accident rates and temporary or total disabilities from conventional accidents are among the lowest in the Corporation for nuclear plant workers.

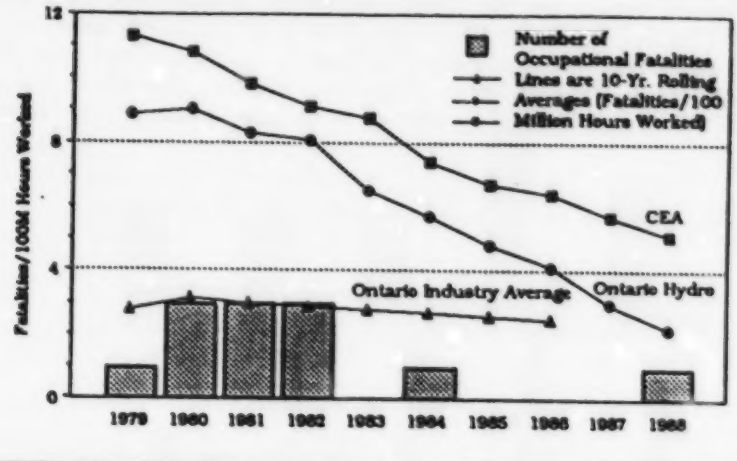


Figure 26 - Fatal Occupational Accident Frequency

Figure 26 shows the fatal occupational accident frequency in Ontario Hydro. The bars at the bottom of the chart represent the numbers of fatalities in the year. It turns out that one of those fatalities in 1982 was among our thermal plant workers; it was the first fatal accident they had had since 1950 when the fossil thermal program began. The rest are spread among linemen, who are a high-risk group, maintenance workers at hydraulic stations, and people who are required to drive motor vehicles occupationally.

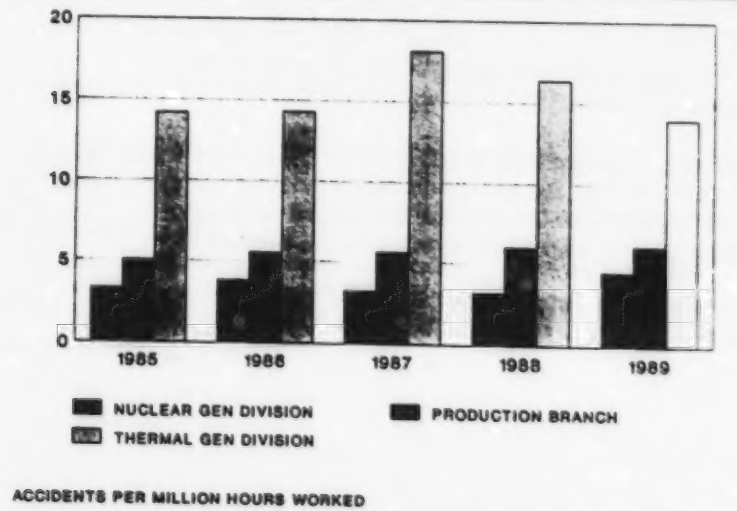


Figure 27 - Disabling Accident Frequency

CCONS/CCHST

Figure 27 shows the disabling accident frequency for the production branch. The two big portions of the production branch are the nuclear generation division and the thermal generation division. You can see that the solid bar is nuclear generation and the tall bars are the thermal generation--quite a marked difference which is really hard to understand when you consider that the facilities are very similar. The bar in the middle is the combination of the two, which shows that we have many more nuclear workers than thermal workers.

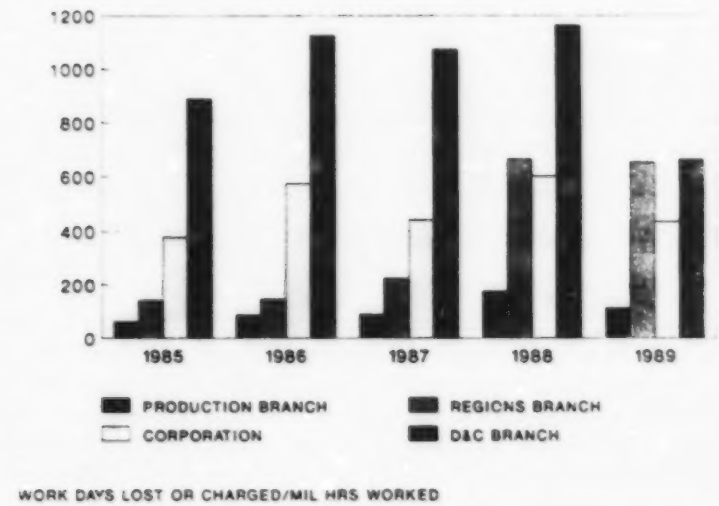


Figure 28 - Disabling Accident Severity Rate

Figure 28 shows the disabling accident severity rate. This is the work-days lost per million hours worked. You can see the production branch is the short, dark bar. The people who have the highest severity rate are the people who work in construction. The second highest are the people who work on lines in the regions.

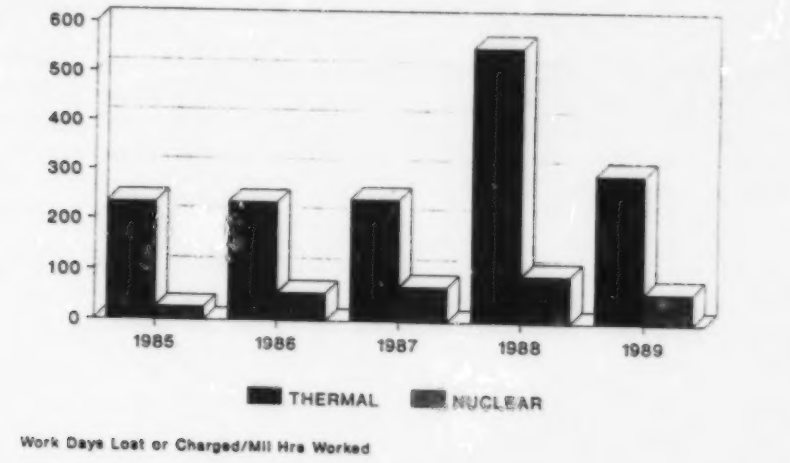


Figure 29 - Thermal and Nuclear Generation Severity Rate

This is a comparison of the severity rate between thermal and nuclear generation--again quite a marked difference.

What about occupational disease? There are several sources of occupational diseases which may be present--ionizing radiation, hazardous chemicals and other physical agents. The problem is that while it is relatively easy to identify that an individual has been exposed, it is much more difficult to measure the dose and even more difficult to identify the effects on workers, particularly if the hazardous material has no specific end point unique to it. This is the case with ionizing radiation. An effect of ionizing radiation is indistinguishable from natural effects at the occupational level.

In the case of ionizing radiation, we monitor and measure all occupational exposures. External radiation doses are measured using TLDs and the internal radiation doses are measured from a routine bioassay sampling program, and where necessary, whole-body counting (a technique to determine the quantity of radioactive material in the body at any time). We are fairly confident that we have a good handle on the exposures. I am not claiming that we know to the last millirem the dose that people have received, but certainly at the higher end of the exposures, the measuring technique is good to +/-10%. At the lower level it may be +/-20%.

	Collective Dose (Whole Body) man-rem		
Year	Ontario Hydro Staff	Contractor Staff	Total
1963	51	0	51
1964	183	5	188
1965	145	8	153
1966	110	5	115
1967	343	62	405
1968	748	151	899
1969	952	347	1,299
1970	1,077	508	1,585
1971	1,423	1,110	2,533
1972	1,491	1,217	2,708
1973	1,957	514	2,471
1974	2,120	328	2,448
1975	2,327	828	3,155
1976	1,821	768	2,589
1977	1,572	336	1,908
1978	1,457	351	1,808
1979	1,785	357	2,142
1980	1,499	485	1,984
1981	1,471	250	1,721
1982	1,469	253	1,722
1983	1,947	488	2,435
1984	1,471	397	1,868
1985	991	228	1,219
1986	1,177	508	1,685
1987	1,180	590	1,770
1988	1,115	404	1,519
	31,882	10,498	42,380

Figure 30 - Collective Dose from the Operation of Ontario Hydro's Nuclear Power Stations 1963 to 1988

One way of trying to put the radiation risk into some kind of perspective is to look at the total doses received by our workers. This table (Figure 30) represents all the radiation dose to Ontario Hydro's workers and to contractors since our nuclear program began. What is interesting about this is that in 1969 the total capacity of our nuclear facilities was about 240 megawatts electrical. In 1988 it was about 12,000 megawatts. We have had almost a 50-times increase but the collective dose has actually decreased. This represents improvements in design and operating techniques since the early days.

What does this really mean in terms of health risks? If one used the ICRP-26 risk estimate, then the total dose experienced by workers in hydro facilities to date ultimately would lead to five additional fatalities from induction of cancer. So in 25 years we would have produced five fatalities, which is about 1 every 5 years. Using the more recent BEIR V risk estimate, on the face of it, would turn out to be more like 1 per year. The big difference between ICRP-26 and BEIR V is that BEIR V in their remit from the committee organizers were told to just evaluate the risks as best they could without fiddling about with the numbers. The need to fiddle about with the numbers arises because, while the effects of high dose and high-dose rate are obvious and can be measured in groups of people such as bomb survivors and people who have been exposed medically, at low dose and low-dose rate it is very difficult if not impossible to see the effects. ICRP-26, when they made their estimate in 1927, used a factor of 2 to correct for the difference between high dose/high-dose rate and low dose/low-dose rate. BEIR V did not do that; they thought it might be reasonable to do it, but that it was not

their job to do it. The evidence for this dose reduction factor is strong in animals but virtually non-existent in humans because there are not the groups of people exposed under the right conditions. It is my view that the BEIR V risk estimate is an upper value.

If you take into account a worker's average annual dose and the latency of the effect, loss of life is in the range of 10-15 years. Trying to make that equivalent to an industrial fatality, where the average is closer to 30 years loss of life, you can come up with an equivalent fatal accident rate which, using ICRP-26, would be about 0.8 per 100 million hours worked; using BEIR V it is about 3.8 per 100 million hours worked. This is based on our average dose.

Within our corporation, we have had ongoing since 1972 an epidemiological study of mortality experience. There are two subsets of data: all male employees ever listed on the Radiation Dose registry and all male employees according to their most recent work location.

DOSE (mili-Sievert)		zero	<50	50 -99	100 -149	150 -199	200+	TOTAL
NEOPLASMS (Cancers)	Obs	9	15	5	2	3	2	36
	Exp	14.55	29.58	3.78	2.91	2.18	3.50	56.50
	SMR	*62*	*51*	*132*	*69*	*138*	*57*	*64*
	CL	*28-118*	*28-84*	*43-308*	*8-249*	*28-404*	*7-206*	*44-89*
CIRCULATION (Heart, Stroke, etc)	Obs	13	32	1	2	2	4	54
	Exp	21.73	42.20	5.28	4.18	3.12	5.01	81.51
	SMR	*60*	*76*	*19*	*48*	*64*	*80*	*66*
	CL	*32-103*	*52-108*	*0-106*	*6-173*	*8-231*	*22-205*	*50-86*
ACCIDENTS (All types)	Obs	10	22	6	1	0	3	42
	Exp	16.74	31.36	5.12	3.07	2.28	2.78	61.34
	SMR	*60*	*70*	*117*	*33*	*0*	*108*	*68*
	CL	*29-110*	*44-106*	*43-255*	*1-183*	*p=.09*	*22-316*	*50-92*
ALL OTHER CAUSES	Obs	2	7	0	0	2	0	11
	Exp	10.56	20.84	2.93	2.20	1.80	2.40	40.52
	SMR	*19*	*34*	*0*	*0*	*125*	*0*	*27*
	CL	*2-68*	*14-70*	*p=.07*	*p=.13*	*15-451*	*p=.10*	*14-48*
TOTAL (All causes)	Obs	34	76	12	5	7	9	143
	Exp	63.57	123.98	17.10	12.36	9.17	13.68	239.87
	SMR	*53*	*61*	*70*	*40*	*76*	*66*	*60*
	CL	*37-74*	*48-76*	*36-122*	*13-93*	*31-157*	*28-130*	*50-71*

Cumulative Mortality Experience 1972-1987, by Lifetime Dose (Ext + Int)

Observed (Obs) and Expected (Exp) deaths, and Standardized Mortality Ratios (SMRs) from 1972 to 1987 in all those male employees of Ontario Hydro ever listed on the Dose Register by cumulative lifetime dose.

Figures include pensioners as well as active pensionable employees.

Where there is at least one observed death, the 95% Confidence Limits (CL) of the SMR are given. If no death has occurred, the probability (p) of observing zero deaths at this level of expected deaths is shown.

Expected figures are cumulative, are age-adjusted by 5-year age-groups, and are based on general male mortality rates in Ontario during the intercensal years 1971-76, 76-81, and 81-86.

Figure 31

Figure 31 shows all our nuclear workers. You can see that to date the number of cancers among our nuclear workers is significantly lower than you would expect when compared to the Ontario male population at large. Similarly the number of deaths from heart disease, accidents and all other causes is significantly less than the population at large. These are the numbers; the interpretation of these numbers is another question.

		Nuclear	Thermal	Other	TOTAL
NEOPLASMS (Cancers)	Obs	28	48	752	828
	Exp	32.95	48.39	888.63	969.96
	SMR	*61*	*99*	*85*	*85*
	CL	*37-94*	*73-131*	*79-91*	*79-91*
CIRCULATION (Heart, Stroke, etc)	Obs	28	67	1635	1730
	Exp	46.27	82.55	1784.41	1913.23
	SMR	*61*	*81*	*92*	*90*
	CL	*41-88*	*63-102*	*87-96*	*85-95*
ACCIDENTS (All types)	Obs	39	18	198	255
	Exp	46.67	29.28	262.07	338.03
	SMR	*84*	*61*	*76*	*75*
	CL	*60-114*	*36-96*	*66-87*	*65-85*
ALL OTHER CAUSES	Obs	7	20	438	465
	Exp	25.35	34.46	675.98	735.79
	SMR	*28*	*58*	*65*	*63*
	CL	*11-58*	*35-90*	*59-71*	*57-69*
TOTAL (All causes)	Obs	94	153	3023	3270
	Exp	183.43	204.55	3741.96	4109.94
	SMR	*58*	*75*	*81*	*80*
	CL	*47-71*	*64-88*	*79-85*	*77-83*

Cumulative Mortality Experience 1970-1987: by Work Location (Nuc/Th/Other).

Observed (Obs) and Expected (Exp) deaths, and Standardized Mortality Ratios (SMR's), in all male employees of Ontario Hydro between 1970 and1987, according to whether most recent work location was a Nuclear Generating Station, a Thermal GS, or elsewhere in the corporation.

Figures include pensioners as well as active pensionable employees.

Where there is at least one observed death, the 95% Confidence Limits (CL) of the SMR are given.

Expected figures are cumulative, are age-adjusted by 5-year age-groups, and are based on general male mortality rates in Ontario during the intercensal years 1971-76, 1976-81 and 1981-86.

Figure 32

Figure 32 compares causes of death for nuclear workers, thermal workers and other workers and a total for the corporation. What is interesting is that the number for the corporation is lower that you would expect. Thermal is slightly lower than you would expect and nuclear is the lowest group we have. What you are seeing is what is called the "healthy worker" effect. People who are employed tend to be healthier than people who are not employed. That explains some of it. Secondly, we have not yet had time for all the ill-health effects to show. The longest time for workers on our dose registry is

28 years. We know that the cancers could appear up to 50 years after exposure. However, the same is also true about thermal workers. The thermal division has been operating 10 to 15 years longer than the nuclear division yet the cancer mortality experience, on the face of it, looks to be worse. My conclusion is that we cannot see the effects of radiation exposure in our workers.

Let us now take a look at risks to the public. Ever since we began operating our nuclear stations we have had routine measurements of emissions of radioactive effluents; we have had environmental monitoring programs to confirm emission monitoring data and also to measure what is in the environment and what we put there. Our ability to measure radioactive materials is significantly better than for most other materials. In the case of tritium we can detect one atom in 10^{18} atoms of tritium, which is one part in a billion billion. From that data we are able to determine, based on average people living an average lifestyle, what the impact is on the public in terms of radiation dose. We estimate that the annual dose to the public is of the order of 180 person-rem per year. Based on ICRP-26 that would translate roughly to 1 fatality every 60 years or using BEIR V, about 1 in every 10 years. The genetic risks are about 30% of the fatality risk.

That is a rough guide to the risks; I have not talked about severe accident risk. The probability of such a catastrophic event is obviously a function of the design of the facility. In the case of the Canadian design, the numbers indicate that the risk of a catastrophic event is 1 in a million per year. The consequences of such a catastrophic event, given the design of the system, is that there would be no acute radiation exposures but certainly there would be some statistical expectation of future deaths based on the amount of radioactive material emitted. It is really quite difficult to grasp what it means because you are dealing with small probabilities. However, if anyone asked me if there would ever be an accident in an Ontario Hydro nuclear power station, I would say that probably there will be. If you asked me what the consequences would be, I would say they would be almost entirely economic in terms of a facility which might not be operable for several years. The public health consequences I would expect not to be measurable.

Having told you about the risks, the next question is "Are there any benefits?" I believe there are. The total cost of electricity produced in Ontario Hydro's nuclear power stations is less than the cost of any of the alternative methods available to produce electricity. Ideally, we would like to produce electricity by pouring water down a waterfall, but we have used all that up. There is some left in the north, but because of the distance it will be very expensive. In the current 25-year plan there is a plan to develop some of that and there is also a plan to redevelop Niagara Falls to squeeze a few more megawatts out of it. Generally speaking, the 12,000 megawatts we currently have which is nuclear we cannot get anywhere else other than by burning coal or oil. If the electricity had been produced by burning oil or coal we would have had to pay for it mostly in foreign currency, which means that we have to produce more to sell abroad to get foreign currency to buy the fuel. That is another economic advantage.

CCOHS/CCHST

CANDU vs Coal Cost Savings (M$)
($ of the year)

Year	Pickering NGS-A Versus Lambton TGS	Bruce NGS-A* Versus Nanticoke TGS	Pickering NGS-B Versus Comparable Coal Station**	Bruce NGS-B Versus Comparable Coal Station**	Total
1976	67				67
1977	90	4			94
1978	107	33			140
1979	129	91			220
1980	126	183			309
1981	147	227			374
1982	124	208			332
1983	104	300	26		430
1984	(11)	293	88	33	403
1985	(109)	187	132	123	333
Total	774	1526	246	156	2702

* NGS-A net energy output includes steam production for the Bruce Heavy Water Plant, which has been 12% of NGS-A output since in-service.

** Assumes that the comparable coal-fired stations would have been built with wet scrubbers.

Figure 33

On an absolute scale if you look at the cost savings of the nuclear plants versus coal, it looks like this--since 1976 to 1985 about $2.7 billion. That goes to the consumer, to members of the public as individuals and also to members of the public as workers in corporations which use lots of electricity.

Coal Purchases Avoided (M$)
($ of the year)

	US Coal	CDN Coal	Total
1971 - 1976	460	-	460
1977	276	-	276
1978	390	-	390
1979	437	110	547
1980	546	155	701
1981	640	190	830
1982	692	172	864
1983	765	238	1 003
1984	850	219	1 069
1985	1 065	235	1 300
Total	6 121	1 319	7 440

Figure 34

In terms of coal purchases avoided, we have, since 1971-1985, saved $6 billion on American coal that we did not have to buy.

There are environmental benefits. Emissions from alternate sources of electricity are averted. In Ontario they would be coal-fired emissions.

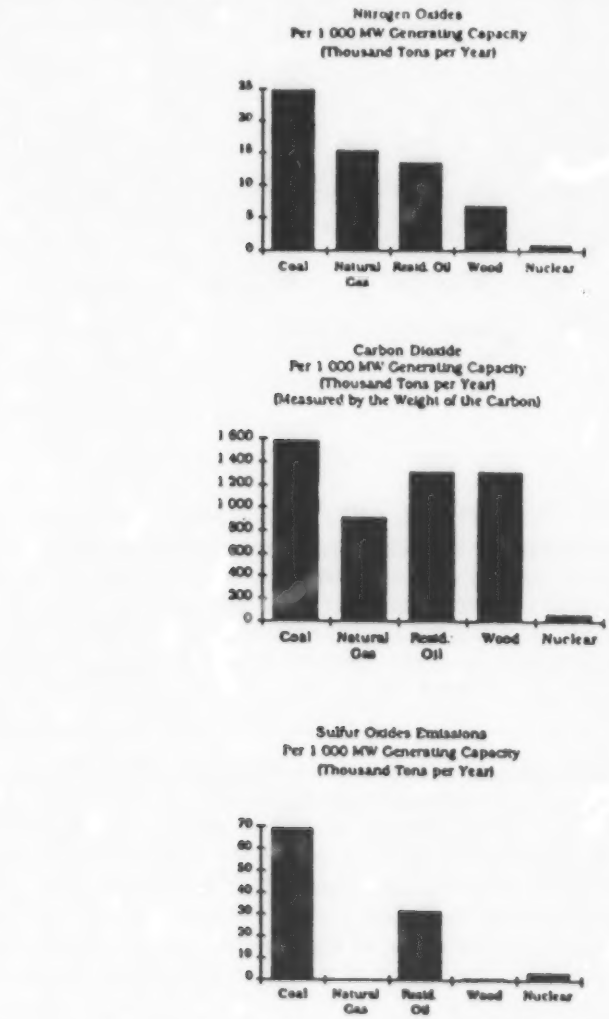
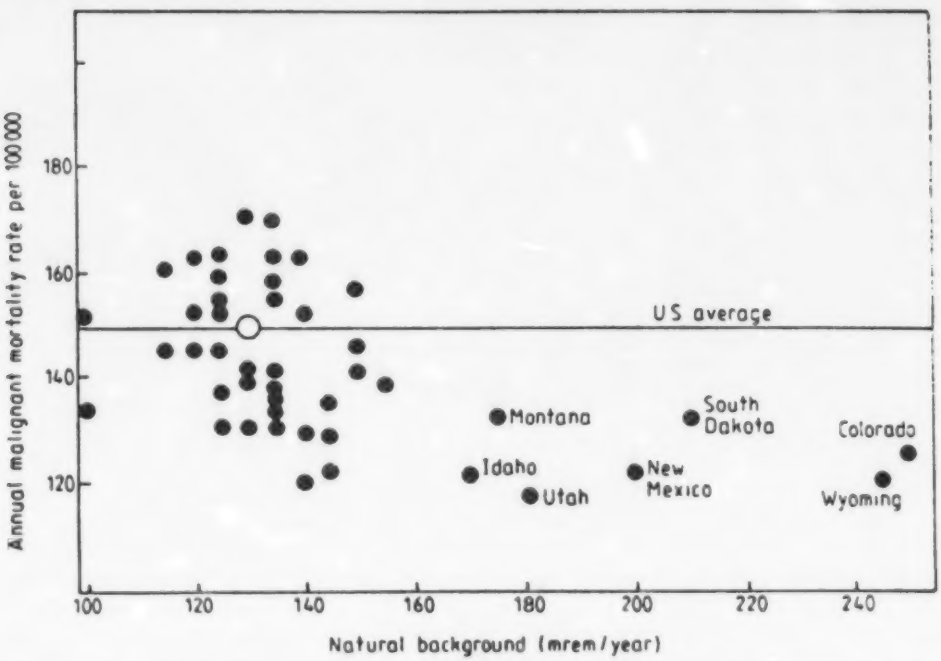


Figure 35

Figure 35 shows the rate of emissions from various sources of electricity. This is a report which came out in April 1990 from the US Council of Energy Awareness and you can see the amount of nitrogen oxides (acid gas), carbon dioxide (greenhouse gas), and sulfur oxides (acid gas) which are averted by not burning coal or natural gas or oil or wood.



Malignant mortality rates for the US white population from 1950 to 1967 by state and natural background.

Figure 36

Quite frankly, no one knows the impact of averting these emissions. Here is an interesting study done in 1973 looking at malignant mortality rates in the US in various states (Fiugure 36). The study looked at the impact of natural background radiation. The very low cancer rates are in states that happen to have very high natural background radiation by a factor of 2 higher than some of the others. This is another graph which on the face of it would seem to show that radiation is good for you, but in reality it is believed that ground level pollution was the cause of the elevated cancer rates in some of the low background states. We know the effect of pollution emitted at low level.

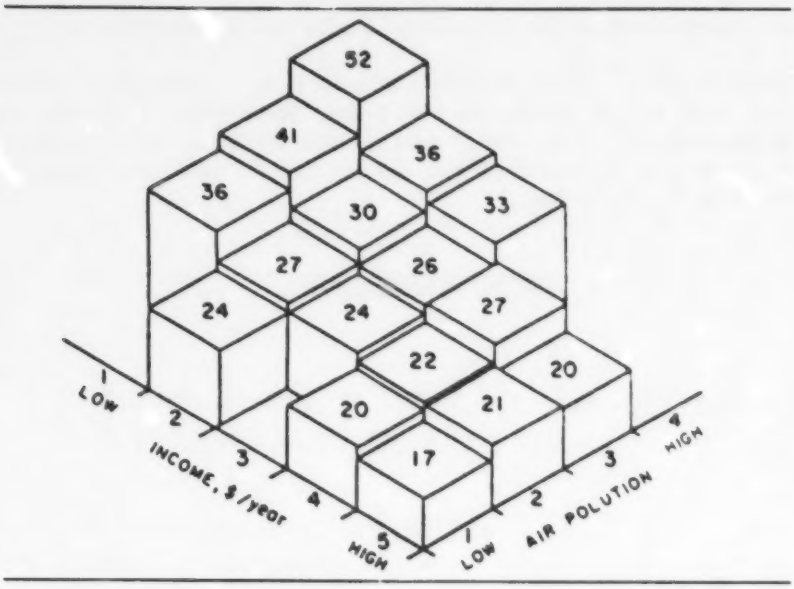


Figure 37

This demonstrates the same thing. This study was done in Buffalo and it relates mortality per thousand per year among males in the age group 50-69 versus income and air pollution level. You can see that being poor and living in a high air pollution area is not very healthy. We are looking at pollution that is released at ground level, as in burning fires and such. In the case of oil-fired or coal-fired plants, we fire it into the atmosphere so the ground level concentrations probably are not that significant.

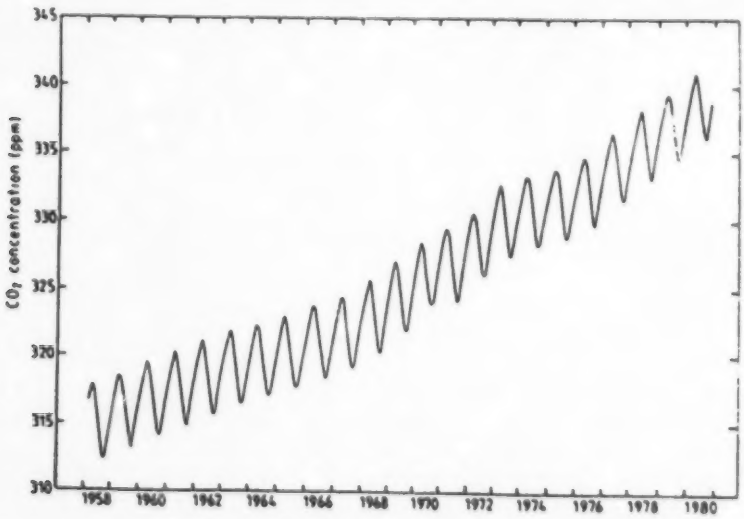


Figure 38

CCOHS CCHST

Figure 38 shows that the concentration of carbon dioxide in the atmosphere is increasing. The consequences of this in terms of health risk is uncertain.

What are the health benefits? There definitely appears to be a connection between the total wealth of a society and its health and well-being. Some fraction of that wealth is spent on life-saving activities. Since the production and use of electrical energy contributes to the total wealth of society, you can say that indirectly electrical energy production contributes to saving lives.

PRESENTATIONS

Radiation Safety in Uranium Mines Project - Communication
J L Chakravatti, Denison Mines

Controversy and Credibility
Fergal Nolan, Canadian Institute for Radiation Safety

CCOHS/CCHST

RADIATION SAFETY IN URANIUM MINES

Lillian Vine

J L Chakravatti of Denison Mines is going to talk about a project which was undertaken by Denison Mines with the Canadian Centre for Occupational Health and Safety and in cooperation with the Atomic Energy Control Board.

J L Chakravatti graduated from the University of Wales in 1964 with a BSc in Mining. He emigrated to Canada in 1968 and worked in the mining industry in Alberta and British Columbia before joining Denison Mines Limited in 1971. Apart from a short period out of Ontario in 1974-75, he has been at Elliot Lake for over 15 years as a Senior Environmental Engineer. He is a member of the Canadian Institute of Mining and Metallugry and of the Water Pollution Control Federation.

J L Chakravatti

I did not prepare a lengthy talk for this afternoon. Because the topic is "Communication," I will take advantage of the facilities available from CCOHS to communicate the project we did in association with the Centre. We have put together a preview diskette on the computer which you can see during the coffee break.

This communication entails a training program which we have developed for uranium mine workers. It is about exactly 2 years ago that the Atomic Energy Control Board, the nuclear regulatory agency in Canada, promulgated some specific regulations respecting uranium mining. These regulations introduced a formal requirement to institute a training program in basic radiation health and safety, acceptable to the Board, to enable the workers to perform their jobs in accordance with these regulations and in a manner that will not create a health and safety hazard to any person. In addition, these regulations require workers completing the prescribed training to be tested for their comprehension of the subject matter and to be certified indicating their proficiency.

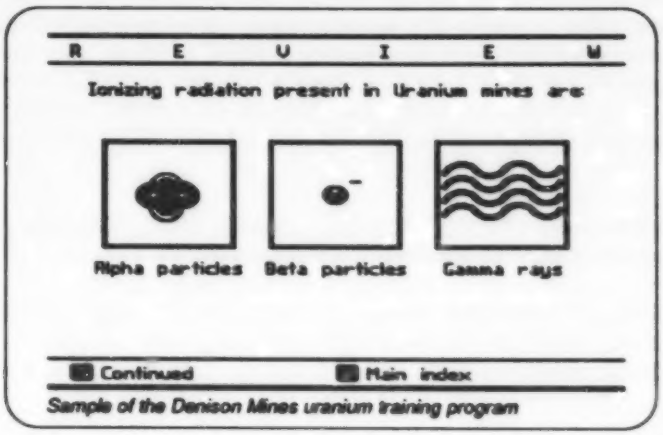
The scope of the subject matter of the training is also specified in these regulations and includes fundamentals of radiation protection; properties and hazards of uranium, radon (and thoron) and their daughters; the purpose and methods of measuring radiation exposure; applicable guidelines and criteria; the proper practices to eliminate, limit or control worker radiation dose including personal hygiene; applicable medical surveillance plan and the reasons therefor; contact persons in matters of health and safety; obligations of workers under these regulations; the health effects of radiation exposure and the added risk to workers of smoking.

It is a formidable task to achieve all which is prescribed, in a topic which is technically challenging and for an audience with a varied academic background and about which society has developed a closed view. The fact that learning is not a passive process is described in an old Chinese proverb:

> Tell me and I will forget
> Show me and I will remember
> Involve me and I will understand

Is it any wonder that the "Nintendo System" is so popular with the children of today! We at Denison, given this tall order under the regulations requirement, felt that if similar enthusiasm could be funneled into learning about radiation safety, the wonders of the earth might be revealed to be as exciting as those of a cosmic creature on a television screen. Our search to become an effective communicator on this subject caused us to join our resources with those from CCOHS to develop a communications module.

Training by interaction



Sample of the Denison Mines uranium training program

We are very excited about the package and thankful for the assistance of the joint health and safety committee at Denison operations for their generous review and guidance in producing these modules. Earlier this year we started our worker training program at Denison as each module was completed. We have altogether four modules and we have been very fortunate to have some dedicated and articulate trainers. It would have been remiss not to include them in the overall program because they themselves are workers. They possess one talent which I do not--being able to communicate with the worker in the worker's own language. It is a distinct advantage to have trainers who can speak the worker's language. In our experience, starting with the WHMIS program, we found it was an excellent way to train workers. This allows communications to be free in both directions. We are proceeding posthaste in the training of all our workers. All four modules take about one full shift, including testing individually with the help of a questionnaire.

I would be willing to answer any questions about this training program. I think you all have had a chance to see it during the breaks.

Ray Kosan - Ontario Hospital Association

I was wondering if the workers are nervous about being tested?

J L Chakravatti

No, it is part of the regulation requirement and that is explained to them at the very beginning of the delivery. They are told what is required in the regulations, why the training is being conducted, that there will be a test and how the test will be carried out. As the workers are going through the session, they have the questionnaire sheet and they answer questions after a part of the training has been completed. It sometimes requires some translating to overcome any reading difficulty. Although the questionnaire is in a multiple choice format, there may be some things that they cannot read. One of the trainers can explain the question on a one-to-one basis and the worker answers what he understood from the training. At the end of the training, these questionnaires are collected.

We have not found any worker taking exception to being tested. If someone fails the test, s/he can come back again for another training session.

Ray Kosan

So they have no worries about being dismissed based on failure in these tests?

J L Chakravatti

No, we have been lucky.

Gerry Armitage

I would like to add that in Ontario Hydro we also have an extensive training program for the nuclear workers. The radiation protection training program runs for four weeks for every worker and includes not only classroom training but practical training. It is a requirement that they pass examinations at the end of the training also. In fact, if they are unable to pass the examinations, they are not allowed to work there.

J L Chakravatti

During the drafting of this regulation by a tripartite body representing the Atomic Energy Control Board, provincial regulatory agencies having an interest in uranium mining, the uranium mining representatives and the worker bargaining agents, industry and labour asked the Atomic Energy Control Board to recognize the formal training requirement by certification. There was a lot of discussion about whether it would be proper to suggest that workers be tested. So the regulations are quite clear on that. But they were drafted in a way that it would not appear to be inhibiting to the incumbents or to new employees. If the incumbents failed to demonstrate after the training that they could comprehend, they should be given consideration for retraining or re-assignment. It has not come to that. One of the advantages we have is that they are not going through a formal lecturer/student forum. We are using some of the workers themselves as trainers and we are using computer-assisted programs which makes the learning process interesting.

CONTROVERSY AND CREDIBILITY

Lillian Vine

Our next speaker is Fergal Nolan, President and Chief Executive Officer of the Canadian Institute for Radiation Safety. Dr Nolan was educated at the Universities of Saskatchewan, Alberta and Oxford, from which he received his doctorate. He taught at both Oxford and Toronto Universities.

From 1979 to 1984 he was senior policy advisor to the Ontario Government for health, education and native affairs for Northern Ontario. In 1981 he was nominated by the Ontario Government to the Board of the new Canadian Institute for Radiation Safety. In 1985 he was invited by the Board to become the first President of the Institute. He became President and Chief Executive Officer in January 1985.

Fergal Nolan

The following is a summary of Dr Nolan's informal presentation, during which he frequently resorted to chalk and blackboard to illustrate and summarize his remarks:

Dr Nolan suggested that no thoughtful person would deny that the issue of radiation safety is one of the most contentious and divisive of any of the social issues that modern societies have to deal with.

At the root of the controversy, he said, is not (as it is often thought to be) the existence of radiation or even people's lack of knowledge about radiation. At the root of the controversy is the question of trust.

People do not know whom to believe and they do not know what to believe. They are deeply sceptical of governments and other public bodies who assure them that radiation exposure problems are amenable to solutions. They are particularly sceptical of the assurance so frequently and unthinkingly given by persons in authority that all is within "acceptable levels"; a notorious and unwittingly offensive phrase, Dr Nolan said, whose use is forbidden at CAIRS.

On radiation issues, he said, expensive exercises in public consultation have seemed to make little headway. This is especially the case when the issue is radioactive wastes. Often, suspicion and hostility increase rather than diminish, even to the point of open political warfare in the communities and regions affected. The issue is polarized. There is no perceived common ground. The result is stalemate.

In the workplace, also, radiation safety is a contentious and often divisive issue. Again, Dr Nolan said, the bone of contention is not itself radiation, but whom to believe. This is particularly so for workers, very many of whom have come to regard virtually any pronouncement on workplace radiation levels by employers and public regulators with the greatest degree of scepticism and suspicion.

This widespread mistrust, suspicion and hostility is frustrating and discouraging for everyone because, in spite of their differences, most people do actually want to see these worrisome radiation issues resolved. But how to find common ground when consensus is lacking? And, in the absence of consensus, how to avoid the temptation to arbitrary imposition of a solution when the issue has reached a stalemate? These questions vex the minds of thoughtful and public spirited people in Canada, whether in government,

industry, unions or among the general public; and not only in Canada, but in numerous other countries where radiation issues of one kind or another badly need quick and speedy resolution.

Fortunately, Dr Nolan said, an organization, unique not only in Canada but in any country, has developed a proven approach to the issue.

The Canadian Institute for Radiation Safety, called CAIRS ("cares"), has found a way to deal successfully with the fundamental problem of trust that is at the root of so much concern and controversy in the workplace and in the community at large on radiation issues.

The Institute has proved successful in applying this approach to workplace radiation safety in an organization as large as Ontario Hydro and to the environmental problem of radioactive wastes in the communities of the Paudash Lake and Bancroft region of eastern Ontario. Its most recent success has been in helping the community of Port Hope, Ontario, reach a consensus on how to deal with its internationally infamous problem of widespread radioactive pollution.

Dr Nolan outlined the philosophy behind the approach developed by the Canadian Institute for Radiation Safety and set out certain principles that guide the Institute in assisting people, whether in the workplace, the environment or the home, to deal practically and effectively with radiation issues.

In particular, he explained the "principle of the crux" developed by CAIRS as both a principle or analysis and as a practical and effective guide to maintaining CAIRS' position as an independent and non-partisan body on radiation issues.

He spoke of the Institute's appreciation of the relationship of science and language as fundamental to the success of the CAIRS approach; and of the related CAIRS principle of "good science in plain language," a task, he said, the difficulty of which no one should underestimate.

He spoke also of the Institute's publicly stated and steadfastly guarded position of being neither pro-nuclear nor anti-nuclear, neither "nuke" nor "anti-nuke," and why CAIRS is able to maintain that unique position with the utmost credibility.

Dr Nolan then described briefly the Institute's programs in occupational health for Ontario uranium miners, in personal radon monitoring in the workplace, and the Institute's national radon monitoring service for homes and schools. He gave a brief account of the Institute's new national laboratories in Saskatoon, Saskatchewan, and of the applied research programs being undertaken there. He also outlined in more detail CAIRS' highly successful work with the Canadian Union of Public Employees and the Joint Health and Safety Committee of Ontario Hydro in dealing with the problem of tritium exposure to the Tritium Removal Facility in Darlington, Ontario.

Dr Nolan welcomed the opportunity to be part of the seminar put on by the Canadian Centre for Occupational Health and Safety (CCOHS). He warmly congratulated J Arthur St-Aubin on his appointment as President and Chief Executive Officer of CCOHS and expressed the hope that the Centre and CAIRS would find ways to cooperate and to assist each another to their mutual benefit in areas of mutual concern.

CONCLUSION

Lillian Vine

It has been a very stimulating and interesting day. For me, it was also an emotional experience of discovering a submerged piece of my subconscious. Gerry, I thank you for that.

I would like to thank the speakers who put up with not enough time and a very crowded agenda. I would like to thank all of you for coming. The support of Canadians has been extraordinarily important to all of us at CCOHS particularly in the past year when things have been very difficult. When I look out at the audience and see that 25% to 30% of you are "repeaters," I am particularly excited. Thank you and please keep coming.

To our staff members, David Charron and Bhawani Pathak, thank you very much. Bob DiMatteo, Jan Deadman, Denis Brown, Gerry Armitage, Chuck Chakravatti, and Fergal Nolan--you have made an incredible contribution to us, and we thank you very much.

I want to tell you what I remembered from way out of my past when you were speaking, Gerry. You talked about why you became interested in the field. I thought my interest in occupational health and safety had actually started after I started at CCOHS. But when you talked about your family, I remembered a very beautiful young woman who studied medicine at the Sorbonne in Paris with my father. She had left Poland as he did to study medicine in France. She and her husband were very close friends of my parents. She had handled radium during her training ; she suffered for some years and died a very untimely and painful death. I had completely forgotten this traumatic incident which happened more years ago than I care to remember and which might explain my interest in our field until I heard you speaking.

Thank you to Maureen Shaw for being here and a special welcome and thank you, Mr St-Aubin, for being with us.

Thank you all for coming; please come back.

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